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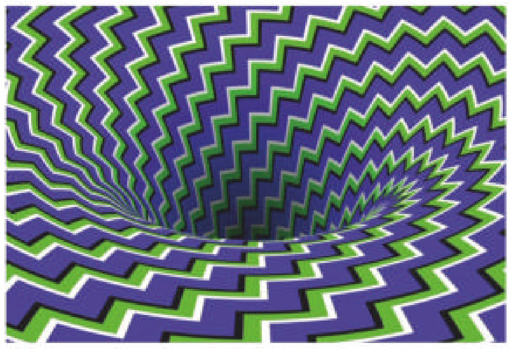

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40 GROSS BUT FASCINATING FACTS

ABOUT YOUR BODY AND THE WORLD WE LIVE IN

HOW WE VOMIT

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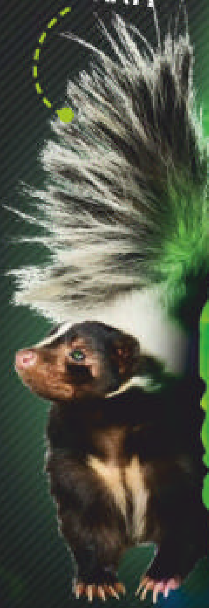
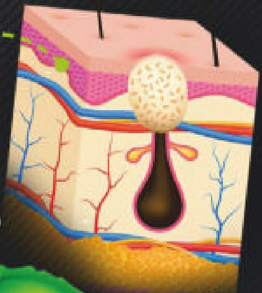


HOW STINKY IS SKUNK SPRAY?

WHAT YOUR POO SAYS ABOUT YOU



WHAT CAUSES A PUS-FILLED PIMPLE?

WHAT'S GROWING ON YOUR FOOD?

WHY THIS LIZARD SQUIRTS BLOOD FROM ITS EYES

WHY THIS PLANT SMELLS LIKE ROTTEN MEAT

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Jaguar I-PACE eTROPHY

Build an Iconic Model

The all-electric Jaguar I-PACE has completed an historic treble at the 2019 World Car Awards. Not only has it won the coveted 2019 World Car of the Year and World Car Design of the Year titles , it has also been named World Green Car.

The I-PACE is the first model ever to win three World Car titles in the 15-year history of the awards.

The dramatic, cab-forward profile, short overhangs and taut, muscular haunches give it a sense of drama which set it apart from other SUVs, which when building with the 40 pieces included you will see as the car grows before you.

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This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. You can recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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WELCOME

The magazine that feeds minds!

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> *“The human body is a breeding ground for mites and bacteria”*
>
> **40 gross but fascinating facts, page 20**

We don't want to put you off reading this issue's special feature, but sometimes the coolest and most compelling science can come from the most disgusting things. Take the slime in the image above, for example. That's hagfish snot, produced as a defence mechanism in huge quantities by this deep sea-dweller. Just a teaspoon of hagfish mucus reacts with seawater to form a mug full of slime, and scientists are studying the stuff to better understand its properties for a range of useful things. We've delved into 40 facts about the world that are just as gross and also fascinating. You can read about them on page 20. Enjoy the issue!

Ben Editor

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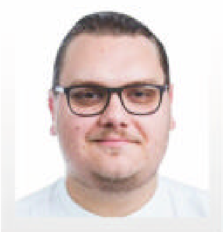
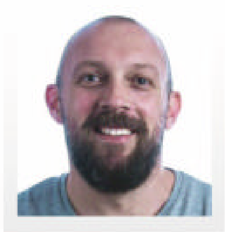
Meet the team…

Nikole
Production Editor
The marvellous Milky Way is our home galaxy – but what do we know about it? Explore it from spiral arm to centre on page 40.



Scott
Staff Writer
Crocodiles are well known as one of Earth's deadliest predators. Learn about how these ferocious reptiles hunt on page 66.

Baljeet
Research Editor
On page 48 we introduce 12 lesser-known scientists who changed the world with their discoveries and inventions.



Duncan
Senior Art Editor
How has a Caterpillar bulldozer been expertly equipped to fight bombs and bullets on the battlefield? Find out on page 62.

Ailsa
Staff Writer
We rely on our vision to make sense of the world, but occasionally our eyes deceive us. Discover optical illusions on page 30.

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CONTENTS

SPECIAL

20 **40 gross but fascinating facts**
Discover disgusting, cool and compelling things about the world you live in

SCIENCE

30 **How optical illusions work**
Why some images play tricks on our brains

36 Your nervous system

38 Light and colour

SPACE

40 **Explore the Milky Way**
Take a trip of the galaxy we call home, spanning across over 100,000 light years

44 SpaceX Dragon capsule

HISTORY

46 **12 scientists who changed the world**
They're not as famous as Einstein, but they still made your life better

52 Inside the White House bunker

AR ZONE!

54 How American women won the vote

TECHNOLOGY

56 **Mega pipes**
How an enormous underwater gas pipeline was built in the Baltic

60 How dental drills work

TRANSPORT

62 **Armoured battlefield bulldozer**
This armoured Caterpillar is built to both clear rubble and defend against a grenade attack

AR ZONE!

64 Inside the world's largest engine

ENVIRONMENT

66 **Killer crocodiles' deadly anatomy**
This ancient species is equipped with an arsenal of hunting tools

68 How do penguins swim?

WIN! AN AIR COOLER WORTH NEARLY £200 Page 78

44 SpaceX Dragon capsule

AR ZONE!

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

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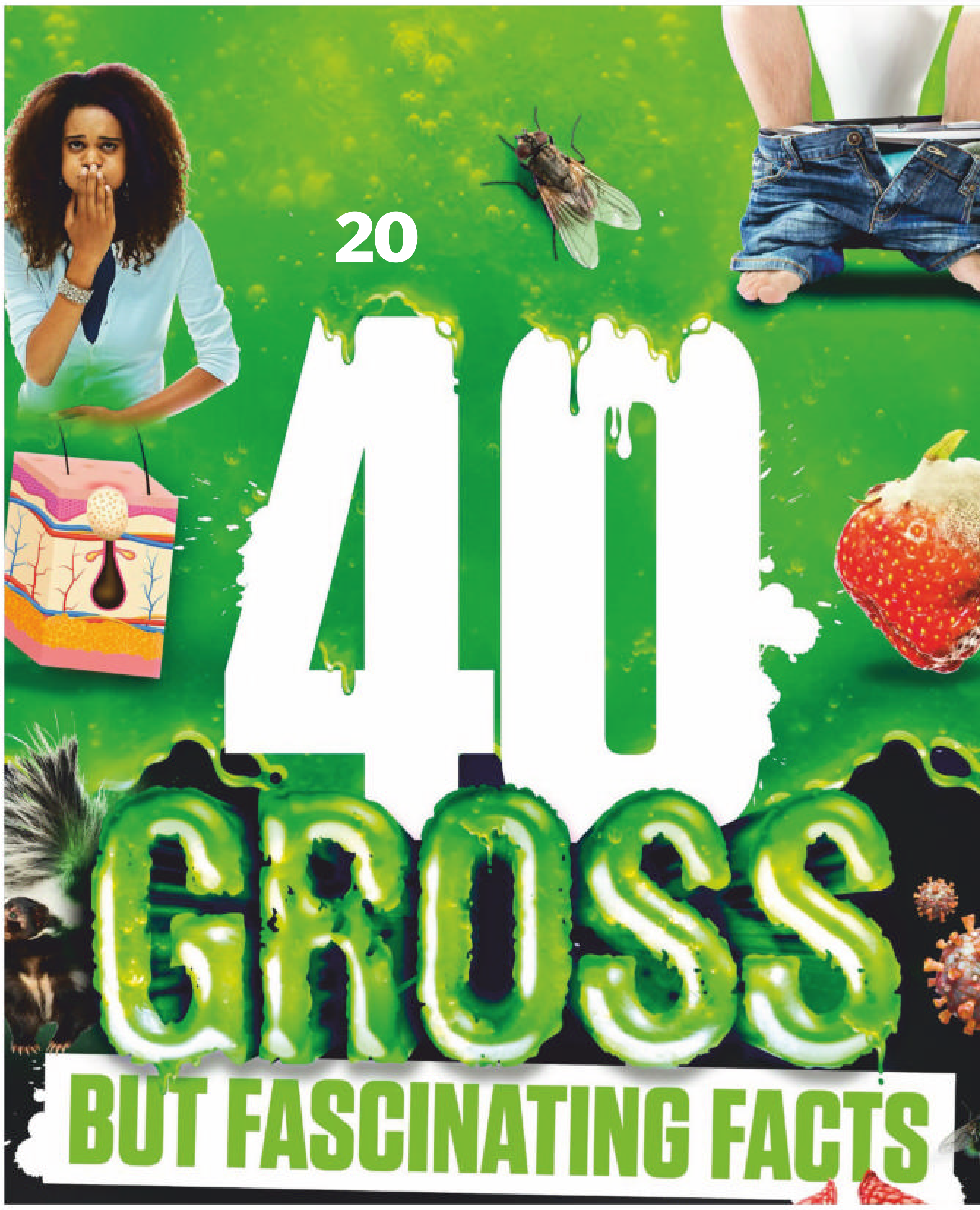
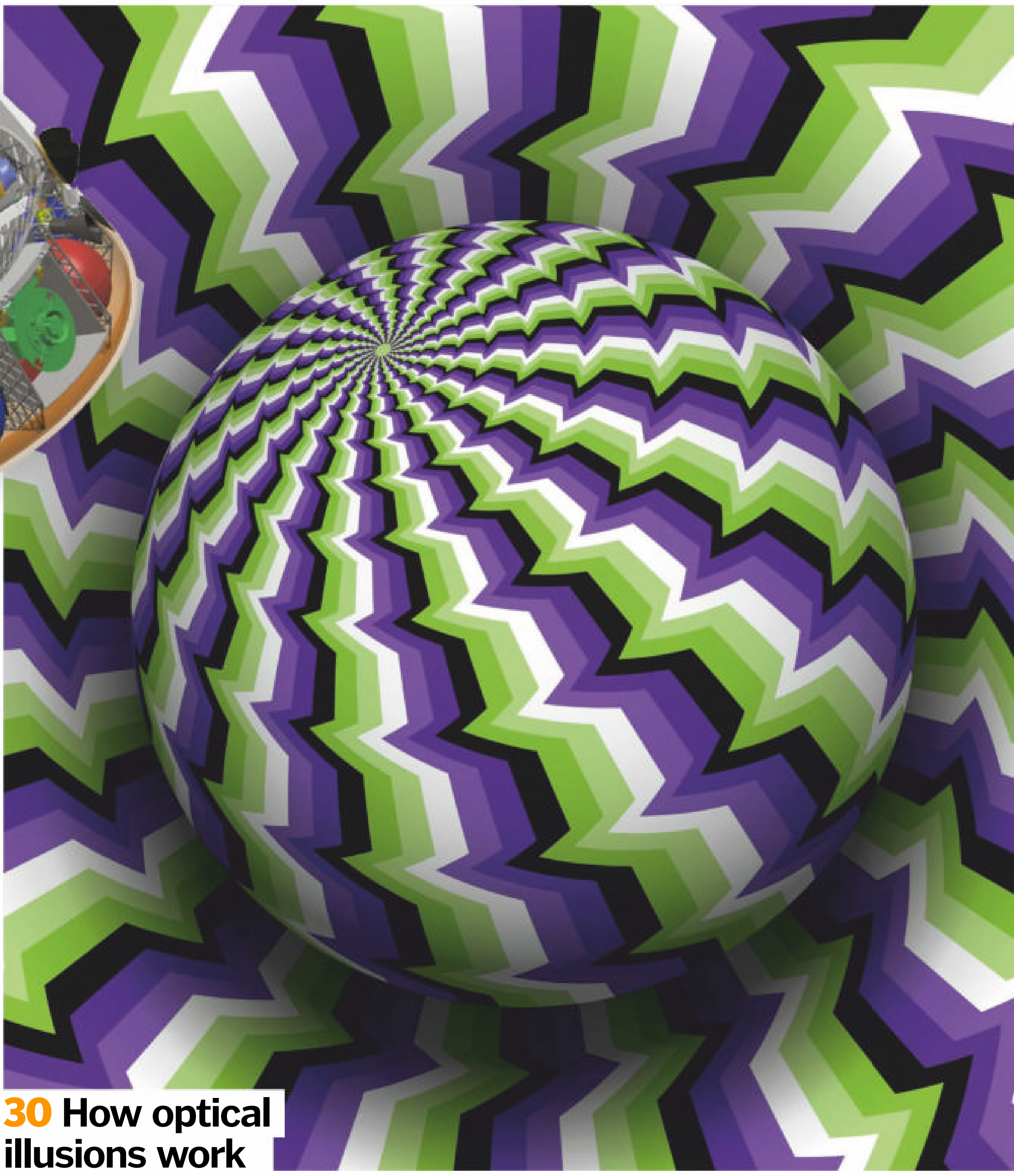
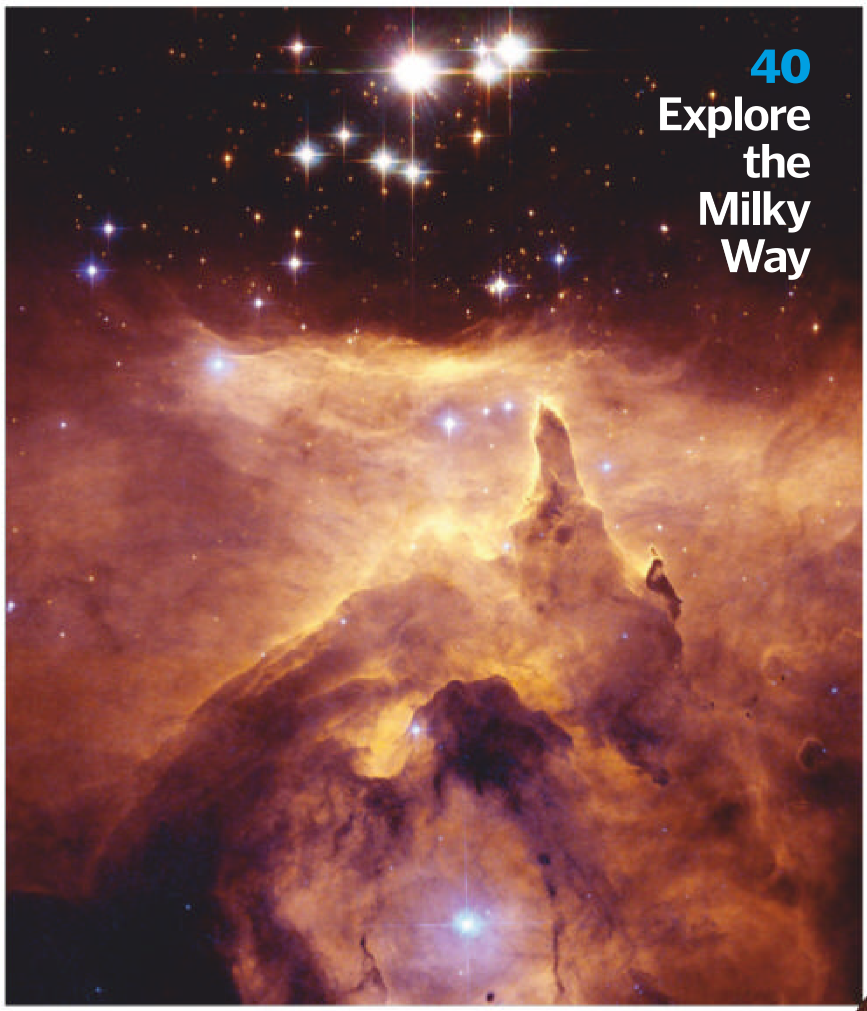
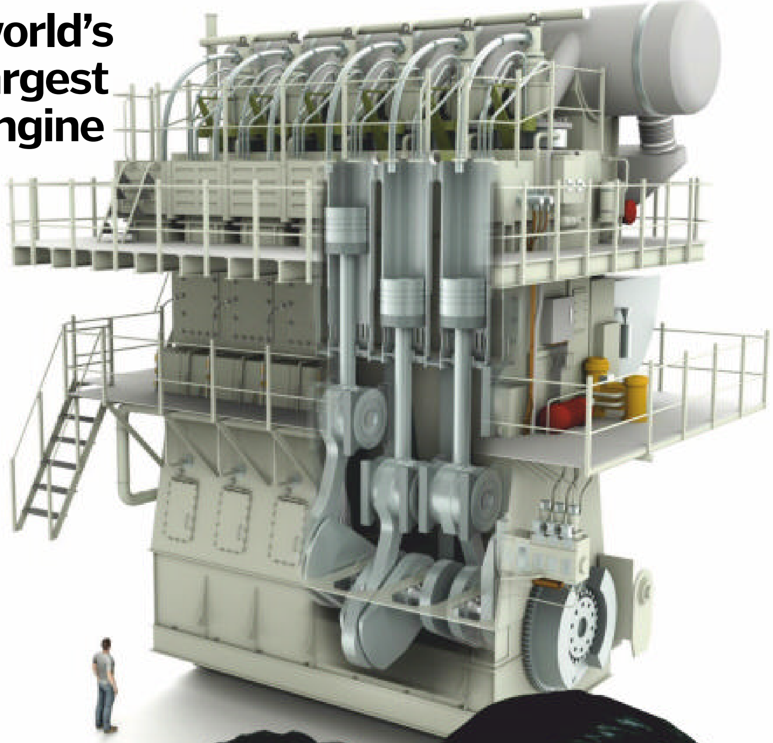




30 How optical illusions work



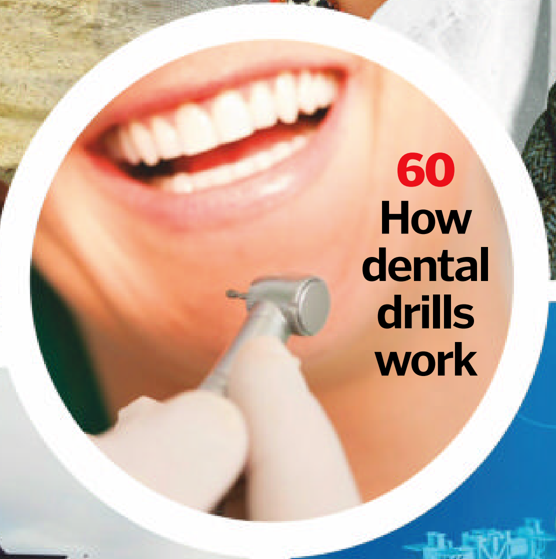
40 Explore the Milky Way



64 Inside the world's largest engine

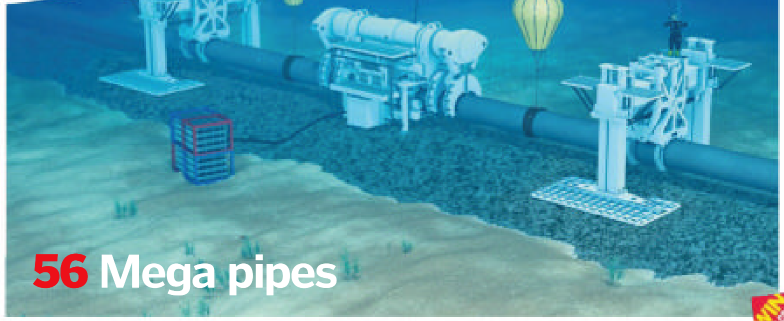
66 Killer crocodiles' deadly anatomy

46 12 scientists who changed the world



60 How dental drills work

52 Inside the White House bunker



56 Mega pipes

62 Armoured battlefield bulldozer

REGULARS

06 Global eye
Science and tech news from around the world

16 Wish list
Fire up the oven and check out these cooking gadgets and apps

69 Three free eBooks
£30 of **How It Works** digital specials for every reader

70 Brain dump
Your questions answered

74 Book reviews

76 Brain gym
Give your brain a workout with our puzzle pages

79 How to...
Grow your own avocado tree

80 Letters
Our readers have their say

82 Fast facts

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ROBERT WINSTON
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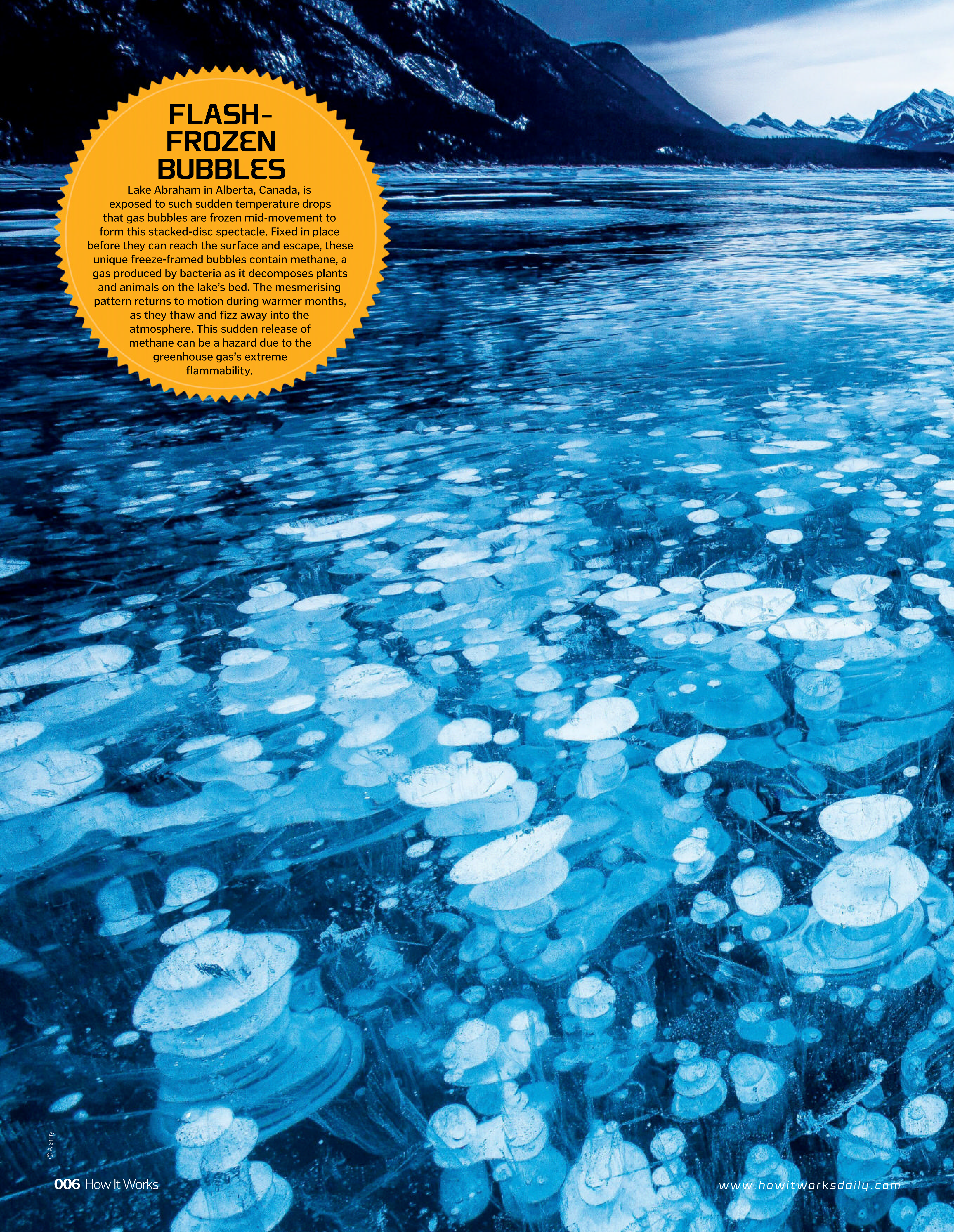
Go to page 18 for great deals



FLASH-FROZEN BUBBLES

Lake Abraham in Alberta, Canada, is exposed to such sudden temperature drops that gas bubbles are frozen mid-movement to form this stacked-disc spectacle. Fixed in place before they can reach the surface and escape, these unique freeze-framed bubbles contain methane, a gas produced by bacteria as it decomposes plants and animals on the lake's bed. The mesmerising pattern returns to motion during warmer months, as they thaw and fizz away into the atmosphere. This sudden release of methane can be a hazard due to the greenhouse gas's extreme flammability.

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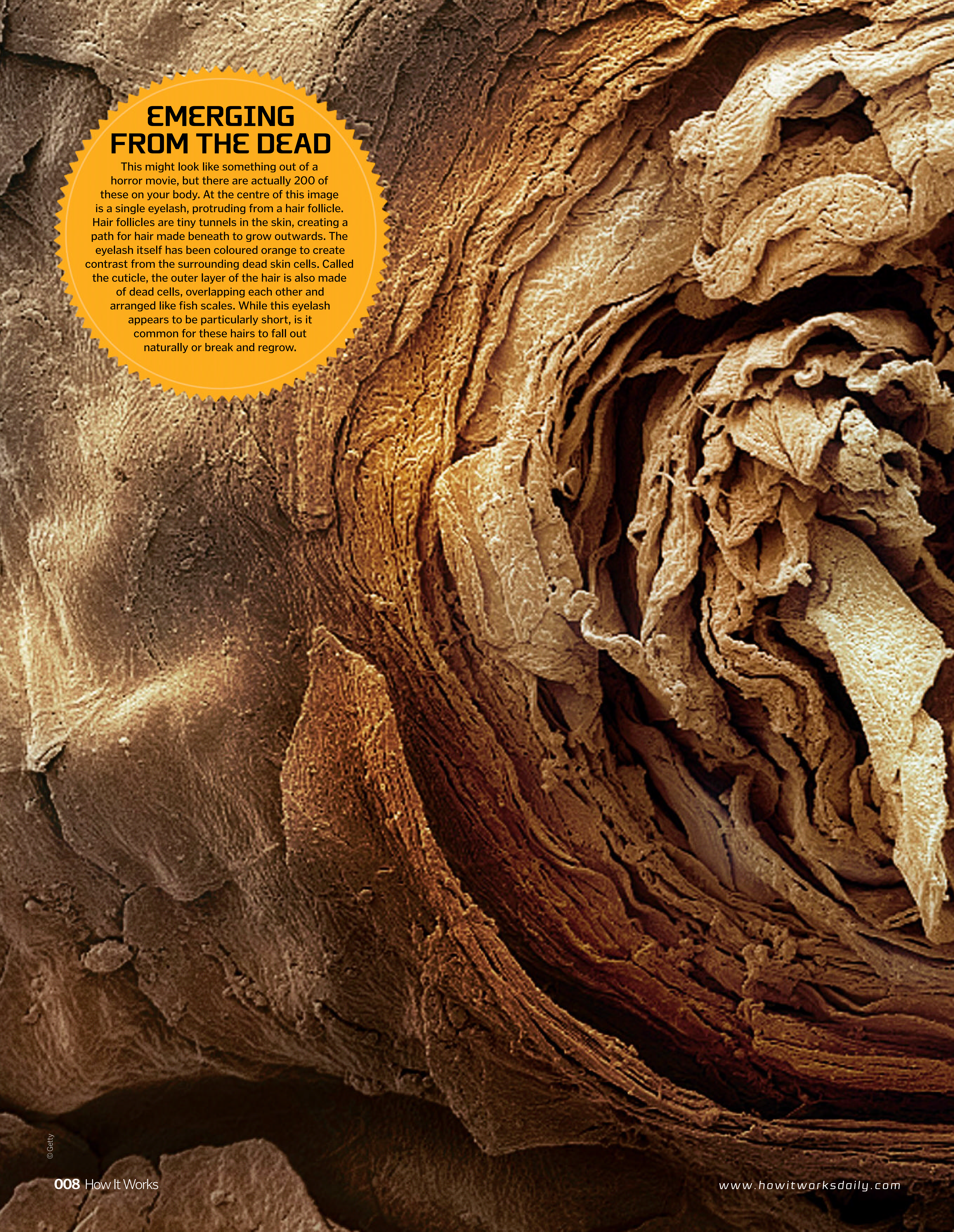

EMERGING FROM THE DEAD

This might look like something out of a horror movie, but there are actually 200 of these on your body. At the centre of this image is a single eyelash, protruding from a hair follicle. Hair follicles are tiny tunnels in the skin, creating a path for hair made beneath to grow outwards. The eyelash itself has been coloured orange to create contrast from the surrounding dead skin cells. Called the cuticle, the outer layer of the hair is also made of dead cells, overlapping each other and arranged like fish scales. While this eyelash appears to be particularly short, is it common for these hairs to fall out naturally or break and regrow.

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PLANET EARTH

Huge diamonds formed near Earth's core

Words by **Rafi Letzter**

© Alamy

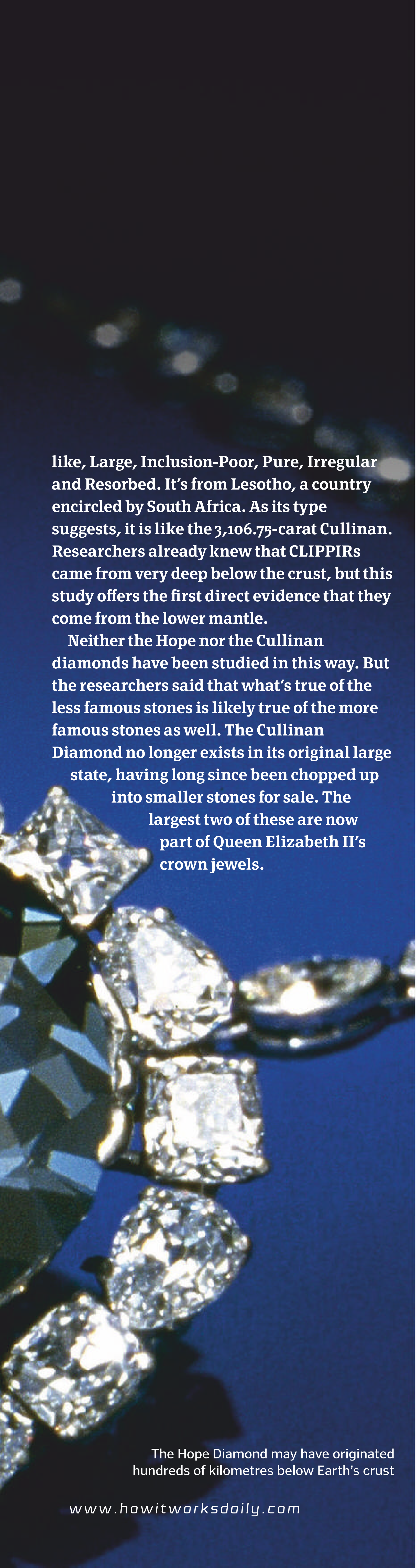
Two of the world's most famous diamonds may have originated super deep below Earth's surface, close to the planet's core. All of Earth's natural diamonds first form deep underground from our perspective on the surface. But from the perspective of this planet's great bulk, their usual births occur relatively far from the core. Zest the Earth like a lemon and you'd uncover diamonds growing at the bottoms of tectonic plates. Those diamonds form about 150 to 200 kilometres deep under pressure that exists just where the crust meets the more fluid outer mantle, or middle layer of the planet. No mines reach that far underground, but some of those diamonds do make their way up to where humans can reach them.

The Hope Diamond, a large and famous stone, as well as the Cullinan Diamond, the largest rough gemstone ever found, are different. They're 'super deep' stones, new research confirms. These boron-blue gemstones likely originated somewhere in the planet's hot mantle, a region between the crust and the liquid outer core of the planet. This new research shows that, at least sometimes, the stones form deep in this hot zone. The recent research found remnants of a mineral called bridgmanite in two less famous diamonds of the same types as the famous gemstones.

All diamonds are crystals made of carbon and various chemical impurities. The type of any specific diamond is determined by the impurities and other conditions present during its creation, so any two diamonds of the same type likely formed in similar conditions.

Bridgmanite is a very common mineral inside Earth, but it doesn't form in the crust or even the upper mantle. "What we actually see in the diamonds when they reach [the] surface is not bridgmanite, but the minerals left when it breaks down as the pressure decreases," said Evan Smith of the Gemological Institute of America. "Finding these minerals trapped in a diamond means that the diamond itself must have crystallised at a depth where bridgmanite exists, very deep within the Earth." This discovery suggests both large blue stones originated in the lower mantle, a fluid zone extending from 660 kilometres deep all the way to the planet's liquid outer core.

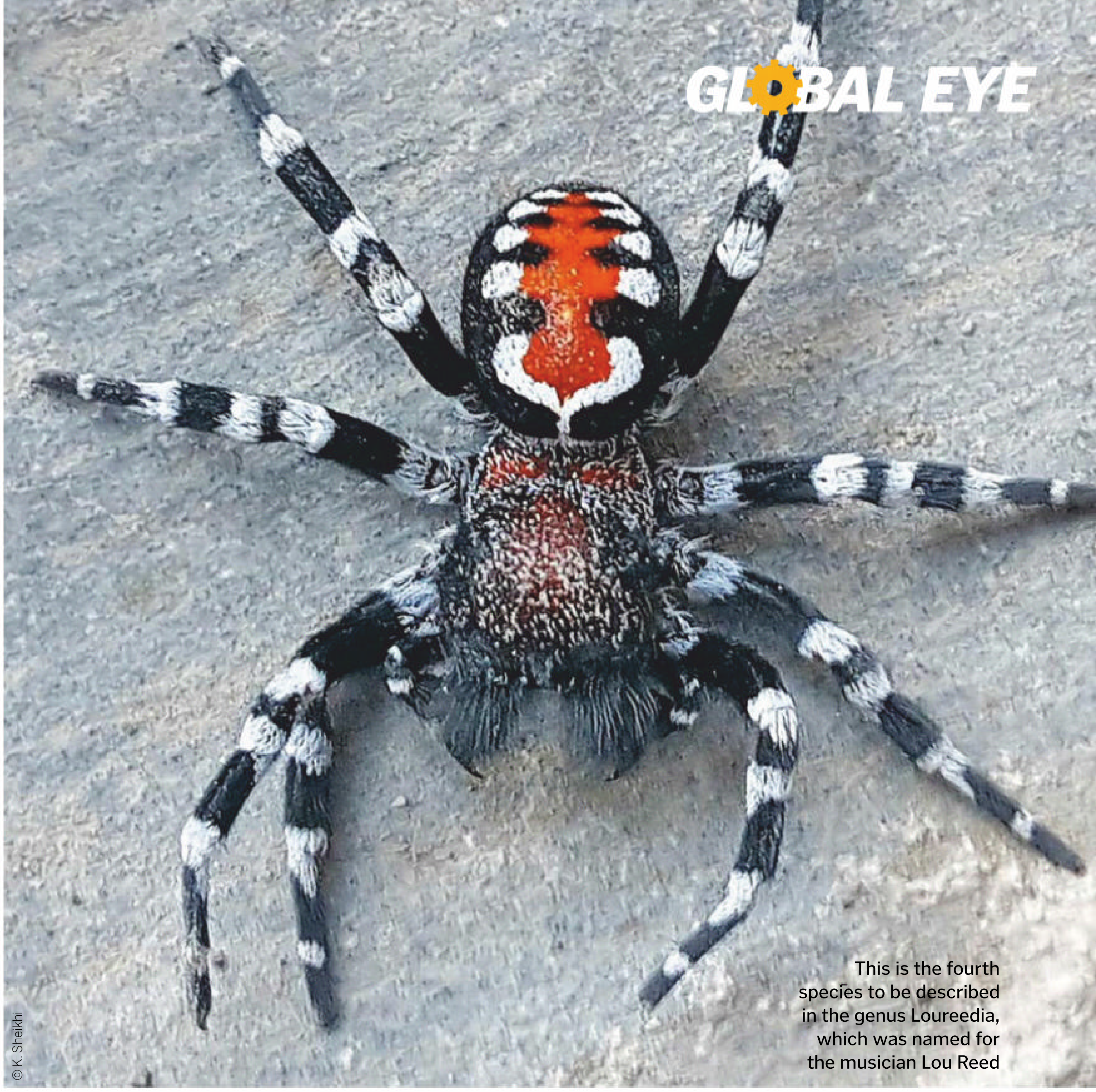
The first, a 20-carat 'type IIb blue diamond' from South Africa, showed evidence of bridgmanite under examination with laser light. The Hope Diamond, at 45.52 carats, is a larger example of the same diamond type. Another diamond, a 124-carat stone about the size of a walnut, is called a 'CLIPPIR' diamond, which stands for Cullinan-



like, Large, Inclusion-Poor, Pure, Irregular and Resorbed. It's from Lesotho, a country encircled by South Africa. As its type suggests, it is like the 3,106.75-carat Cullinan. Researchers already knew that CLIPPIRs came from very deep below the crust, but this study offers the first direct evidence that they come from the lower mantle.

Neither the Hope nor the Cullinan diamonds have been studied in this way. But the researchers said that what's true of the less famous stones is likely true of the more famous stones as well. The Cullinan Diamond no longer exists in its original large state, having long since been chopped up into smaller stones for sale. The largest two of these are now part of Queen Elizabeth II's crown jewels.

The Hope Diamond may have originated hundreds of kilometres below Earth's crust



© K. Sheikhi

This is the fourth species to be described in the genus Loureedia, which was named for the musician Lou Reed

ANIMALS

Scientists discover spider wearing 'Joker' make-up

Words by **Mindy Weisberger**

A newfound spider species wears a striking red-and-white pattern on its back that resembles the grin worn by Batman's long-standing nemesis, Joker. The resemblance is so uncanny that the researchers who described the arachnid named the species after actor Joaquin Phoenix, who portrayed the tormented, smiling villain in the 2019 film *Joker*.

Ironically, the colourful spider belongs to a genus that was named for the late punk rock icon Lou Reed, who famously wore black and rarely smiled. Scientists discovered *Loureedia phoenixi* in Iran, making it the first Loureedia spider to be identified outside the Mediterranean region. The genus, first described in 2018, now includes four species.

On the backs of the male *L. phoenixi* spiders, a splash of vivid red stands out against a background of white, much like the Joker's unnerving smile contrasts with his white facial make-up. However, you'd need magnification to see it clearly, as the spider's body measures only about eight millimetres long.

Discovering Loureedia spiders is challenging because the arachnids are active above ground only for a three-week period each year. "These spiders spend most of their lives in their subterranean nests," Iranian arachnologist and taxonomist Alireza Zamani said. Males leave their burrows to hunt for females "usually from late October to mid-November," and spiderlings come to the surface when they leave their mother's nest, he explained.

So far scientists have collected and described only male *L. phoenixi* spiders. However, the search will continue for the elusive females, targeting locations where males have been found. "Ideally, if you have enough time and patience, it would be interesting to track a wandering male. He should know how to find the female better than anyone else," Zamani said. "This way you would also have the chance of observing and photographing the actual mating behaviour, which has not been documented for any Loureedia species yet," he added.

IN ASSOCIATION WITH LIVESCIENCE

An artist's impression of the luminous blue variable star that mysteriously vanished

© ESO/L. Calçada

SPACE

Star 2.5 million-times brighter than the Sun disappears

Words by **Brandon Specktor**

In 2019 scientists witnessed a massive star, millions of times brighter than the Sun, disappear without a trace. Recently, a team of astrophysicists attempted to solve the case of the disappearing star by providing several possible explanations. Of these, one twist ending stands out: perhaps, the scientists suggested, the massive star died and collapsed into a black hole without undergoing a supernova explosion first, a truly unprecedented act of stellar suicide.

"We may have detected one of the most massive stars of the local universe going gently into the night," said researcher Jose Groh. "If true this would be the first direct detection of such a monster star ending its life in this manner," said study lead author Andrew Allan.

The star in question, located about 75 million light years away in the constellation Aquarius, was well studied between 2001 and 2011. The bloated orb was a superb example of a luminous blue variable (LBV), a massive star approaching the end of its life and prone to unpredictable variations in brightness. Stars like this are rare, with only a handful confirmed in the universe so far. In 2019 Allan and his colleagues hoped to use the European Southern Observatory's Very Large Telescope to learn more about the distant LBV's mysterious evolution, only to discover that the star had seemingly completely vanished from its host galaxy.

Normally when a star much larger than our Sun reaches the end of its life, it erupts in an enormous supernova explosion. These explosions are easy to spot, as they stain the sky around them with ionised gas and powerful radiation for many light years in every direction. Following the blast the dense core of leftover stellar material may collapse into a black hole or a neutron star, two of space's most massive and mysterious objects. The missing LBV left no such radiation. It simply disappeared.

To investigate this mystery, the researchers looked back at previous observations of the star taken in 2002 and 2009. They discovered that the star had been undergoing a strong outburst period during this time, jettisoning enormous amounts of stellar material at a much faster rate than usual. LBVs can experience multiple outbursts like this in their temperamental old age, causing them to glow much more brightly than usual. The outburst likely ended sometime after 2011.

This could explain why the star appeared so bright during those early observations. Still, it does not explain what happened after the outburst that caused the star to vanish. One explanation could be that the star dimmed considerably after its outburst and was then further obscured by a thick veil of cosmic dust. If this were the case then the star could reappear in future observations.

The weirder and more exciting explanation is that the star never recovered from its outburst, but instead collapsed into a black hole without going supernova. This would be a rare event, the team conceded. Given the star's estimated mass before its disappearance, it could have created a black hole measuring 85 to 120 times the mass of Earth's Sun, though how this could have happened without a visible supernova is still an open question. Further observations of the distant, star-eating galaxy are required before this case can be officially closed.

PLANET EARTH

Massive underwater rivers discovered off the coast of Australia

Words by **Yasemin Saplakoglu**

Massive, underwater rivers have been discovered hidden off Australia's coasts by robotic ocean gliders. These rivers could be critical for moving material from the coasts to the deep ocean, scientists have said. Called 'dense shelf water cascades', the hidden rivers form when shallow water on the coasts loses heat during the colder months. This water is already highly salty due to evaporation during the summer months. This cold, salty stream of water in the inner portion of the continental shelf – the edge of the continent that's typically submerged in shallow water – is denser than deeper water. Driven by the difference in density, this river of water flows offshore along the ocean floor.

Now a group of researchers at the University of Western Australia has analysed data collected between 2008 and 2019 with ocean gliders from eight locations on Australia's coastline. The data "is the equivalent to spending more than 2,500 days at sea," said Dr. Tanziha Mahjabin, of UWA Oceans Institute.

As part of Australia's Integrated Marine Observing System, autonomous underwater vehicles deployed along the coasts collected data on the temperature and salinity – salt concentration – of the water. These measurements allowed researchers to deduce the water's density, revealing the presence of these underwater rivers.

The team of scientists found that the underwater rivers are a regular occurrence during the autumn and winter months in Australia across a span of 10,000 kilometres. They also found that the underwater rivers could withstand high winds and high tides that often stir up the water, a finding that's a "unique occurrence globally".

The underwater gliders were also equipped with sensors to detect organic matter and chlorophyll, a green pigment found in plants, algae and cyanobacteria. The underwater rivers in Australia, they found, serve as transport channels for material and matter across the continental shelf and deeper into the ocean.

"The coastal ocean is the receiving basin for suspended and dissolved matter that includes nutrients, plant and animal matter and pollutants and represents an important component of the ocean environment, connecting the land to the deeper ocean," said Yasha Hetzel, a researcher at the University of Western Australia's Oceans Graduate School.

Port Stephens in Australia is one of the places where the robotic gliders found an underwater river

© Getty

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The radiation may have come from a nuclear power plant in Russia

STRANGE NEWS

Mysterious radiation spike detected over Scandinavia

Words by **Tia Ghose**

Radioactivity levels have spiked in the atmosphere over northern Europe, and that could indicate damage at a nuclear power plant in western Russia, according to a Dutch health agency that has analysed the data. The radioactive spike suggests damage to a nuclear fuel element. However, the Russian nuclear power operator Rosenergoatom has denied problems related to facilities in Kola and Leningrad, the two nuclear plants operating in the region.

Several Scandinavian watchdog agencies detected the elevated levels of the radionuclides, or radioactive isotopes. Radionuclides are atoms whose nuclei are unstable; the excess energy inside the nucleus gets released through radioactive decay. In particular, concentrations of the radionuclides cesium-134, cesium-137 and ruthenium-103 rose in parts of Finland, southern Scandinavia and the Arctic, confirmed Lassina Zerbo. Though these pose no harm to humans, they are by-products of nuclear fission.

"The radionuclides are artificial – that is to say they are human-made. The composition of the nuclides may indicate damage to a fuel element in a nuclear power plant," said an official with the National Institute for Public Health and the Environment in the Netherlands, which analysed the isotope data. Because so few measurements have been taken, monitoring agencies weren't able to identify a specific source.

HISTORY

Ancient humans ate snakes and lizards

Words by **Mindy Weisberger**

People who lived 15,000 years ago in what is now Israel feasted on snakes and lizards, archaeologists have discovered. Prior excavations in the Levant, a geographic region that historically included Israel, Palestine, Lebanon and parts of Syria and Jordan, unearthed thousands of bones belonging to lizards and snakes. Animal bones are usually found where ancient people once lived if the animals were being eaten. But it was unknown if lizards and snakes were part of the human diet or if their bones were left behind by other predators.

By experimenting on the bones of modern squamates, the group that includes lizards and snakes, researchers developed visual references for different types of surface damage, such as erosion, burning or digestion by birds of prey.

When the scientists compared these patterns to damage in squamate bones found at the el-Wad Terrace, a cave site near Israel's Mount Carmel that was occupied by humans between 11,500 and 15,000 years ago, they determined that many of the ancient bones had been eaten by people.

At the el-Wad Terrace settlement, the site was densely layered with animal remains, of which "a high percentage" belonged to lizards and snakes. Nearly 3,000 squamate remains, mostly vertebrae, were collected at el-Wad, making up about 33 per cent of all the animal remains at the site.

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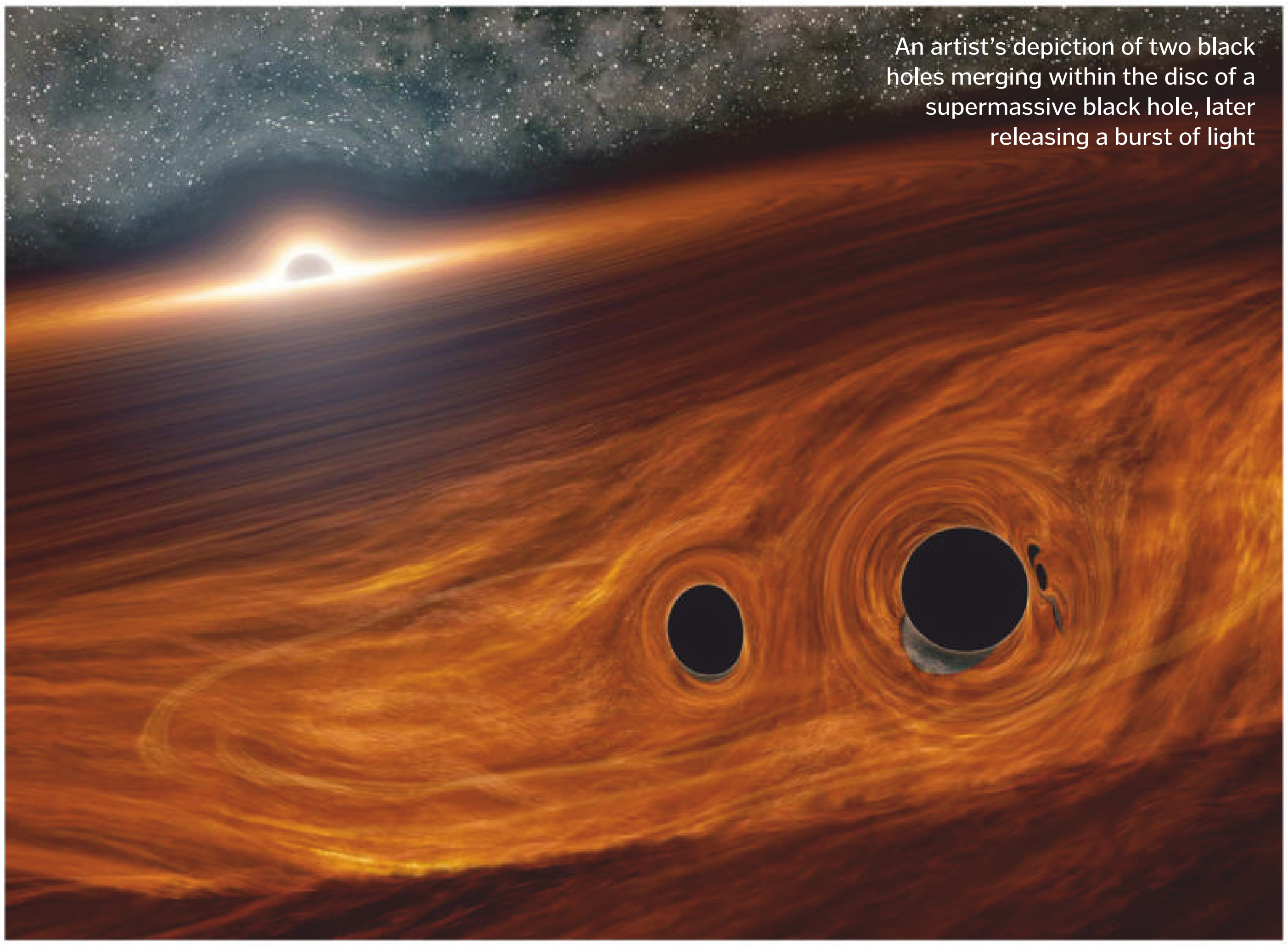
The legless European glass lizard (*Pseudopus apodus*) was likely a part of the ancient human diet


An artist's depiction of two black holes merging within the disc of a supermassive black hole, later releasing a burst of light

© Caltech/R. Hurt (IPAC)

SPACE

Scientists spot flash of light from colliding black holes

Words by **Meghan Bartels**

Black holes aren't supposed to make flashes of light. It's right there in the name: black holes. Even when they slam into each other the massive objects are supposed to be invisible to astronomers' traditional instruments. But when scientists detected a black hole collision last year, they also spotted a weird flash from the crash.

On 21 May 2019 Earth's gravitational wave detectors caught the signal of a pair of massive objects colliding, sending ripples cascading through space-time. Later, an observatory, the Zwicky Transient Facility (ZTF), caught a blast of light. As scientists looked at the two signals they realised both came from the same patch of sky, and researchers started wondering whether they had spotted a visible black hole collision.

Here's what scientists think happened in this strange case: the two black holes that merged were locked in the disc surrounding a quasar, a supermassive black hole that shoots out blasts of energy. "This supermassive black hole was burbling along for years before this more abrupt flare," said Matthew Graham, the project scientist for ZTF.

That in and of itself isn't so strange, however, according to his colleague. "Supermassive black holes like this one have flares all the time," co-author Mansi Kasliwal said. "They are not quiet objects, but the timing, size and location of this flare was spectacular."

Scientists suspect, based on the pairing of gravitational waves and light, that the flare sprang from two small black holes merging within the accretion disc of the supermassive black hole. The supermassive black hole's incredibly strong gravity affects the smaller stuff in the disc, even other black holes.

The flash of light doesn't come from the merger itself, the scientists think. Instead the force of the merger sends the now-a-little-larger black hole flying off through the gas surrounding it in the supermassive black hole's accretion disc. In turn the gas produces the flare after a delay of days or weeks, the theory goes, according to the statement. In the case of this event, scientists detected the flare about 34 days after the gravitational wave signal. Though that's not a guarantee that this explanation fits what happened, the researchers said.

"The flare occurred on the right timescale and in the right location to be coincident with the gravitational-wave event," Graham said. "We conclude that the flare is likely the result of a black hole merger, but we cannot completely rule out other possibilities."

HISTORY

Genes from 'culturally extinct' people discovered in living humans

Words by **Laura Geggel**

The last known members of the Indigenous Beothuk people of Newfoundland were thought to have died out 200 years ago. But genes from these people have been found in a man living in Tennessee today.

Shanawdithit, a Beothuk woman who died of tuberculosis in 1829, was the last known Beothuk. The group had thrived in Newfoundland with as many as 2,000 people there until the Europeans arrived in the early 1500s, bringing disease and pushing the Beothuk inland away from their traditional fishing and hunting grounds, which led to their starvation.

However, even though the Beothuk culture is extinct, their genes are not. Scientists have deiscovered Beothuk genes identical to those of Shanawdithit's uncle in a Tennessee man. They also found fairly well-matched genetic sequences in members of the modern-day Ojibwe – also known as the Chippewa – people, said researcher Steven Carr.

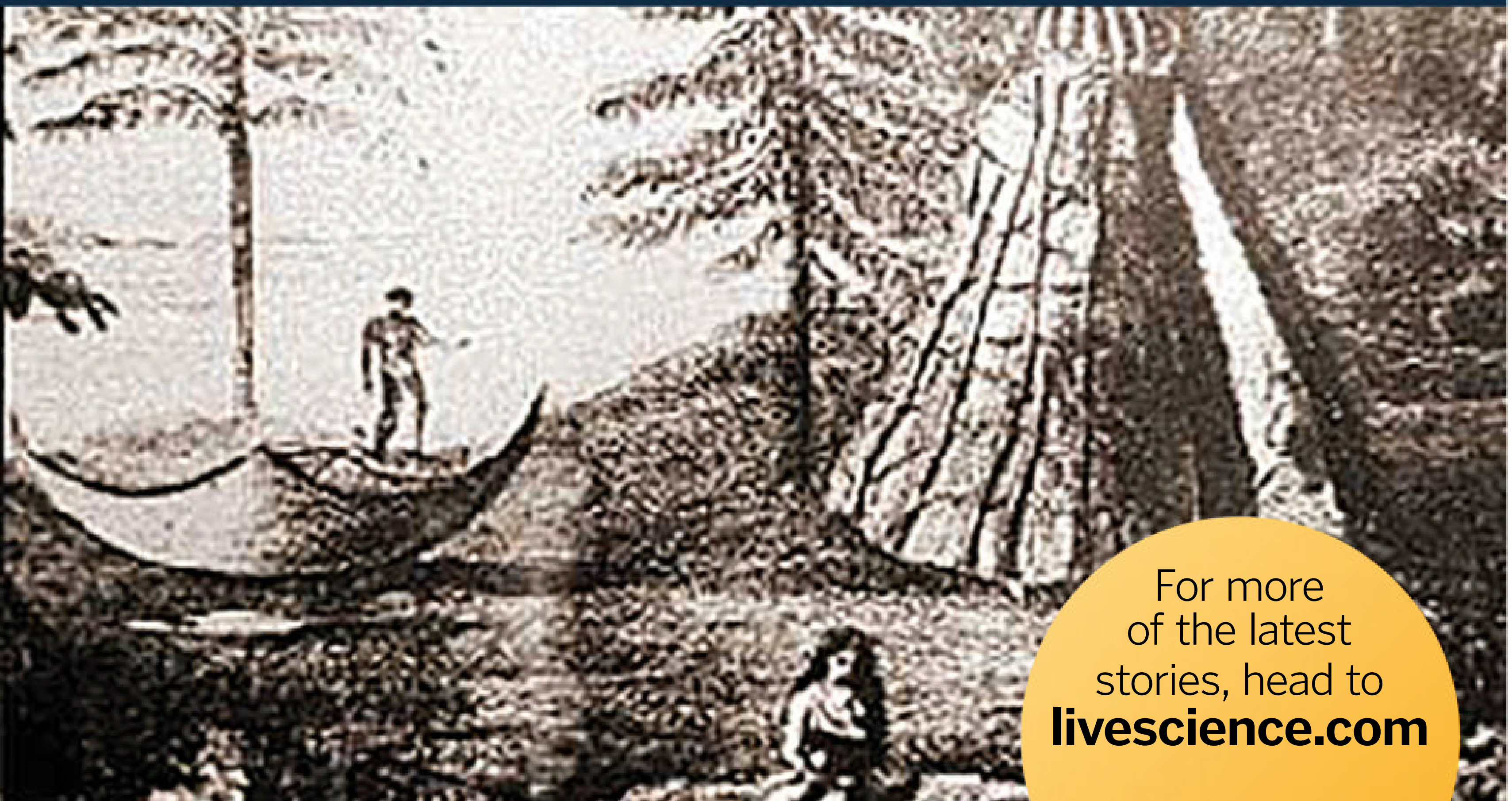
The idea that the Beothuk live on isn't surprising to other Indigenous groups from the Newfoundland region. For instance, the oral traditions of the Miawpukek First Nation, the easternmost tribe of the Mi'kmaq people, a group whose history and geography overlap with that of the Beothuk, hold that Beothuk descendants have survived through the ages.

Carr decided to investigate the genetic sequences in part because "everybody wonders what happened to the Beothuk," he said. "There are people that claim descent from the Beothuk Indians," even though they don't have evidence to support such family ties. For instance, in 2017 a woman in North Carolina claimed to be of Beothuk descent after a commercial ancestry company, using incomplete data, mistakenly suggested this ancestry.

Earlier in 2017, researchers reported that there was no close genetic relationship among three Indigenous groups in Newfoundland: the Maritime Archaic, who lived in Newfoundland from about 8,000 to 3,400 years ago before mysteriously disappearing; the Palaeo-Eskimo, who visited and then lived on Newfoundland from about 3,800 to 1,000 years ago, meaning that they overlapped with the Maritime Archaic and the Beothuk, the indigenous group who lived on Newfoundland from about 2,000 years ago to just 200 years ago.

Carr most recent investigation reanalysed the already published genetic data from the Beothuk. In a nutshell, he looked at mitochondrial DNA – genetic data passed down from mothers to children – taken from the archaeological remains of 18 Beothuk individuals and the skulls of Shanawdithit's aunt and uncle, Demasduit and Nonosabasut, respectively. These skulls had been stolen in 1828 and sent to the University of Edinburgh, but were repatriated to Newfoundland in March after a long campaign by the Mi'kmaq and other Indigenous groups.

A drawing of a Beothuk camp in Newfoundland © Alamy



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The latest **smart kitchen** ga

© Revolution Cooking

R180 high-speed smart toaster

■ Price: **$299.95 (approx. £237.50)**
www.revcook.com

Looking to upgrade your breakfast? The R180 might just be for you. Using the touchscreen control panel, select from five different bakery items including bread, bagels and English muffins and set your preferred level of browning. Once the bread is automatically lowered inside, the R180 display will reveal a countdown timer for when it's ready. Boasting three toasting modes – fresh, frozen or reheat – and an automatic alert when it's time to empty the crumb tray, who knew toast could be so high tech?

© GE Appliances

GE® Smart Microwave

■ Price: **$144 (approx. £114)** www.geappliances.com

They are a common staple in any modern-day home, but how smart can a microwave be? GE Appliances has created a microwave that not only performs typical cooking tasks, but does so without manual instruction thanks to 'scan-to-cook technology'. Using the WiFi-enabled app, simply scan the barcode on your favourite microwave meal and it will automatically set the right time and temperature. Google Assistant and Alexa compatible, just ask the microwave to cook or defrost your food.

Stagg EKG+ Electric Kettle

■ Price: **$199 (approx. £157.50)** www.fellowproducts.com

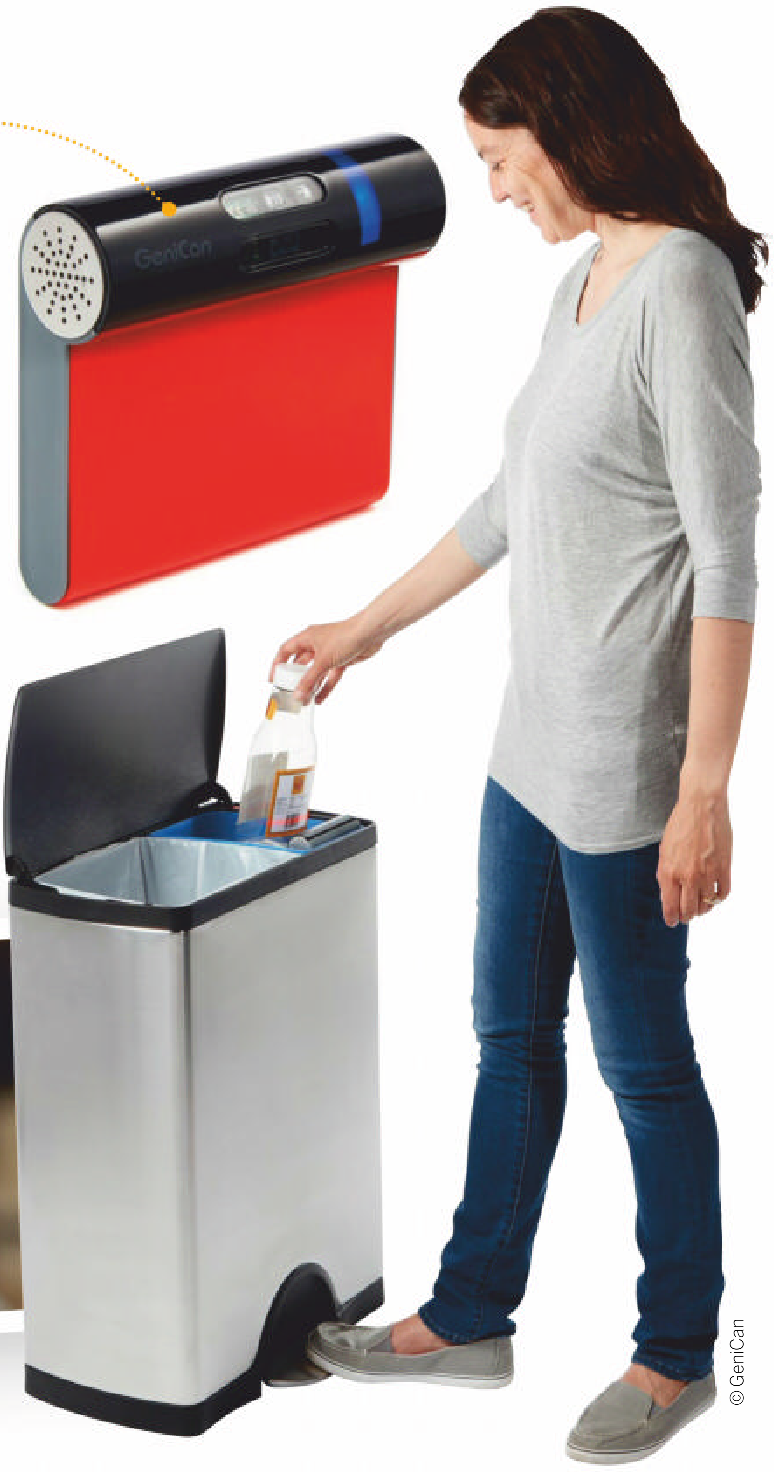
Take making tea and coffee to the next level with the Stagg EKG+ by Fellow. Bluetooth-enabled, this smart kettle gives you complete control over your morning brew. From remotely controlling the perfect temperature to switching it on while you're in bed ready for when you get downstairs, this smart kettle is a great addition to any smart kitchen. The Stagg EKG+ is powered by a 1,200-watt heating element, boiling water in a flash and efficiently holding heat for longer.

© Fellow

GeniCan

■ Price: **$149.99 (approx. $118.70)**
www.genican.com

At some point we've all stood in a supermarket forgetting what we needed, or worse still coming home to find we've forgotten to buy something. Attempting to keep us aware of what's missing from our cupboards, the GeniCan is a compact scanner that sits on your bin, scanning items as they pass by. Simply by scanning product barcodes, the GeniCan adds it to the shopping list. If you're throwing away orange peel, for example, detecting something is entering the bin without a barcode, the GeniCan will ask you what it was so it can add it to the list.



© GeniCan

Pico Model C

■ Price: **$399 (approx. £315.70)**
www.picobrew.com

Imagine having a brewery in your kitchen, sipping on fresh ale and beer without leaving the house. The Pico Model C by PicoBrew can make this dream a reality. Without needing any prior knowledge of home brewing, this self-sufficient machine brews a myriad of different beers from a diverse selection of grains and hops supplied by PicoBrew. Simply load the grains into the machine, which will automatically detect the recipe and brew for two hours. You are then able to ferment and carbonate your brew in the provided keg for homemade beer.

© PicoBrew

MEATER+

■ Price: **£99 / $99**
www.meater.com

If you're a keen meat eater, then the MEATER+ could be a great addition to your kitchen. Unlike most meat thermometers the MEATER+ keeps you updated on the internal temperature and cooking time on your smartphone. Using the companion app, receive suggestions for the perfect temperature for different meats and watch as it rises.

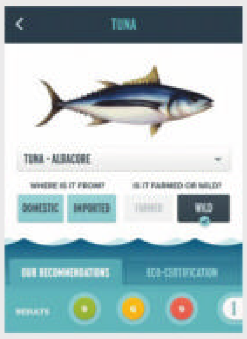
© MEATER

APPS & TOOLS

Seafood Watch

■ Developer: **Monterey Bay Aquarium**
■ Price: **Free / Google Play / App Store**

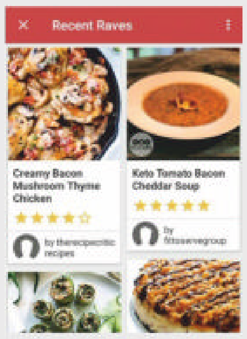
Keep on top of where your fish comes from – whether it's cooking at home or dining out – with this sustainability app.



BigOven

■ Developer: **BigOven.com**
■ Price: **Free / Google Play / App Store**

With over 500,000 recipes, the ability to organise shopping lists and use up leftovers, this app is a great way to get inspired in the kitchen.


Recent Raves
Creamy Bacon Mushroom Thyme Chicken
Keto Tomato Bacon Cheddar Soup

Kitchen Planner 3D

■ Developer: **Andrey Ovchinnikov**
■ Price: **Free / Google Play**

Simple to use, this app allows you to design and organise your kitchen space by virtually dragging and dropping potential appliances and storage.

Toca Kitchen

■ Developer: **Toca Boca**
■ Price: **Free / Google Play**

Let your children explore the world of cooking with this fun and interactive app. They can learn to slice, fry and boil and complete recipes for their favourite characters.

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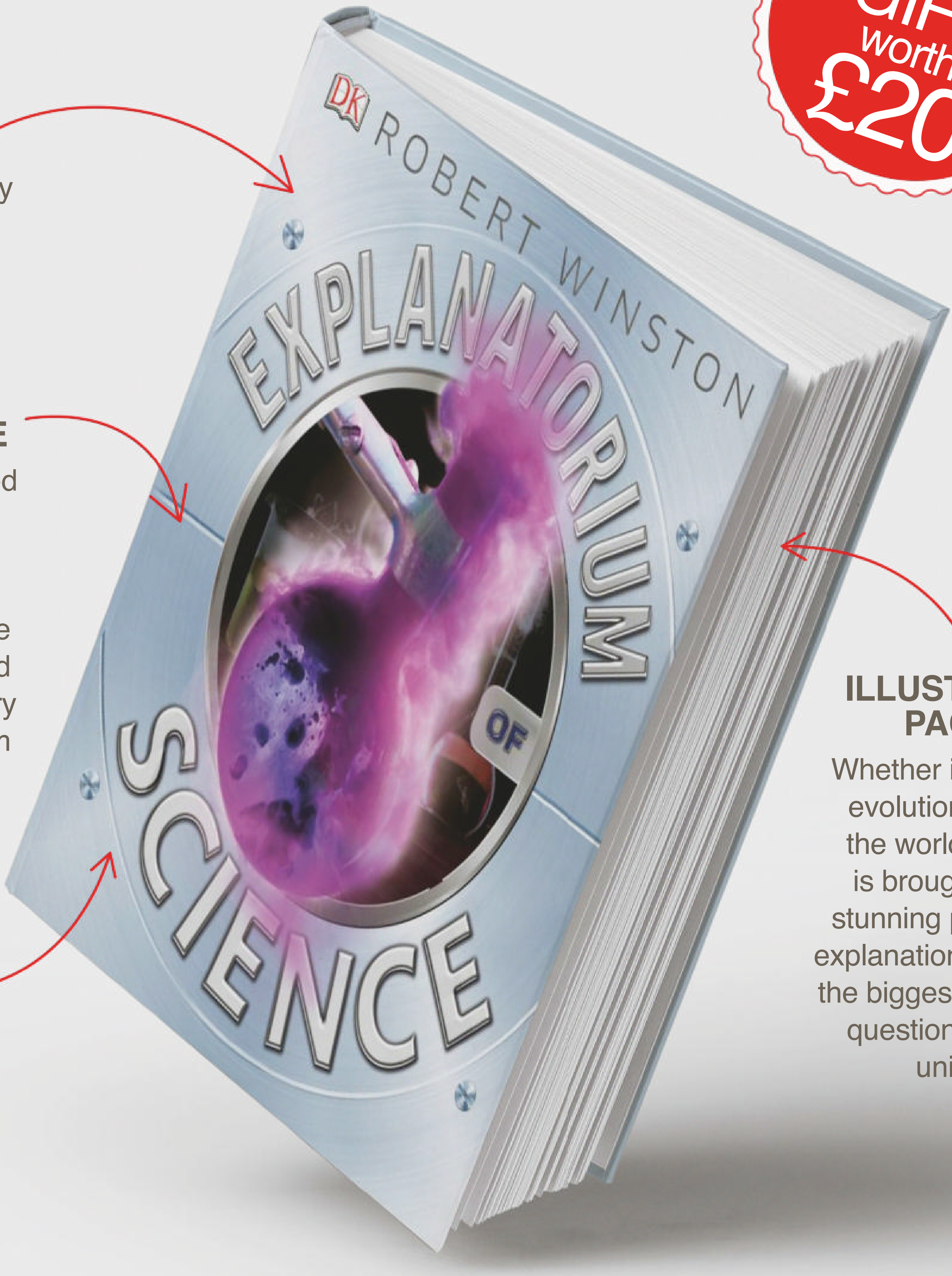

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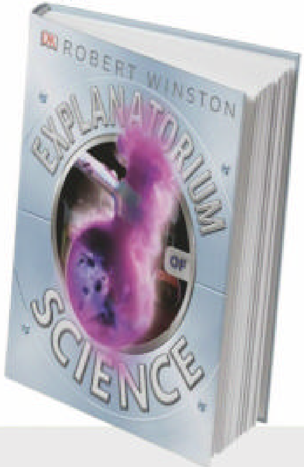

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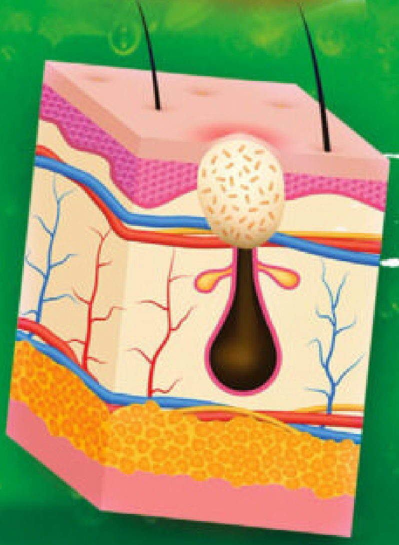


40 GROSS BUT FASCINATING FACTS

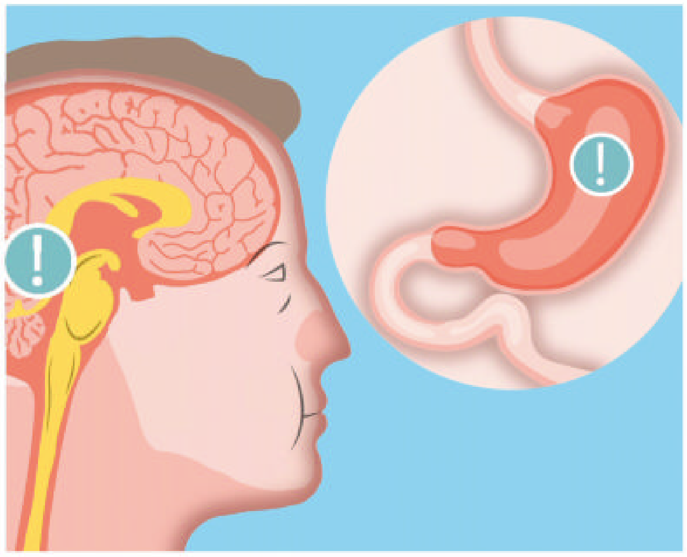
ABOUT YOUR BODY AND THE WORLD WE LIVE IN

Words by **Scott Dutfield**

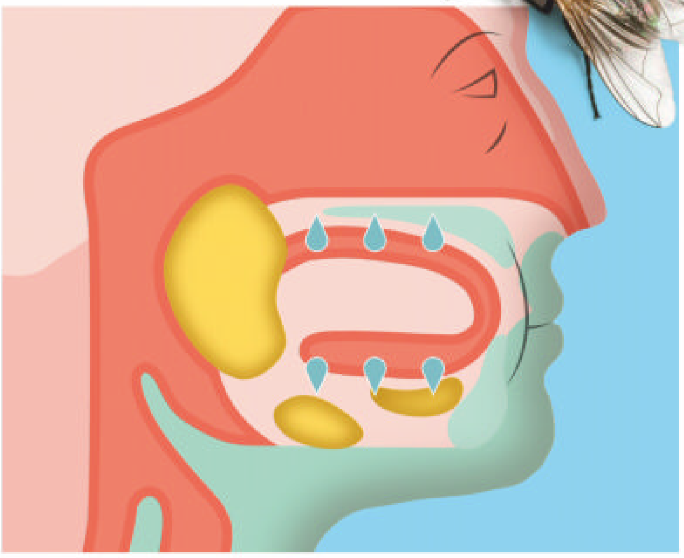
DID YOU KNOW? 2 *The average person has between 1.5 and 2.5 million mites all over their body*

1 VOMITING DISSOLVES TEETH

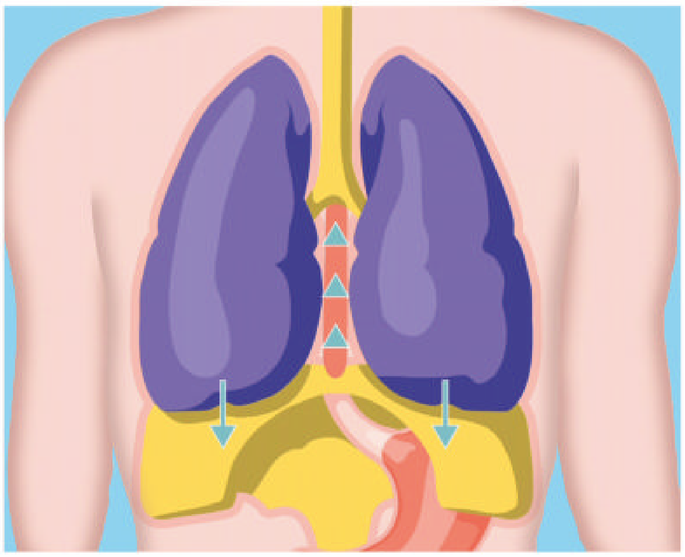
From tummy to toilet, what happens to our bodies when we spill our guts?



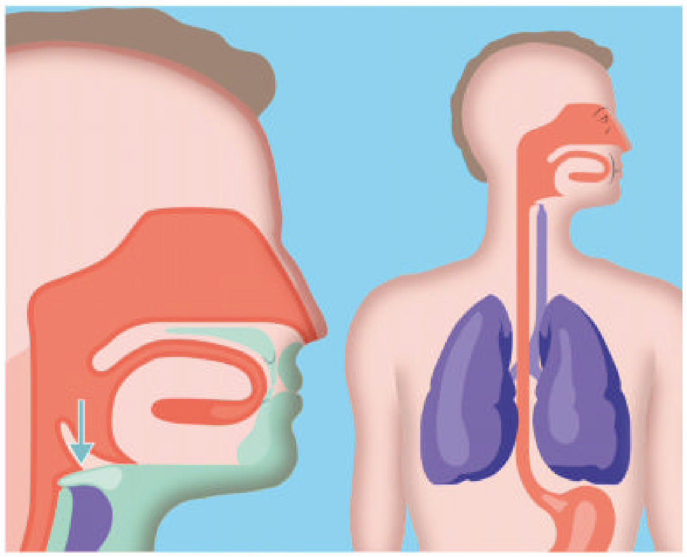
1 Signal
An area of the brain's medulla oblongata known as the chemoreceptor trigger zone (CTZ) receives a warning that the contents of our stomach need to be evicted.



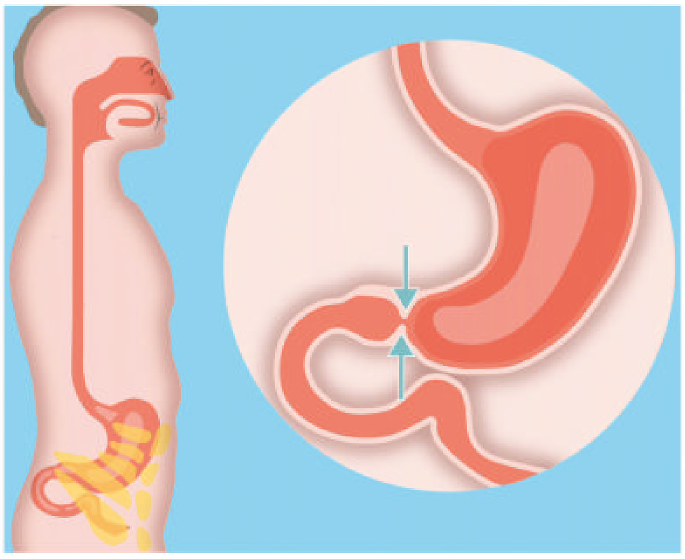
2 Preparation
To prepare the mouth and teeth for the incoming stomach acid – since it can wear away enamel and cause other damage – our salivary glands produce alkaline saliva for protection.



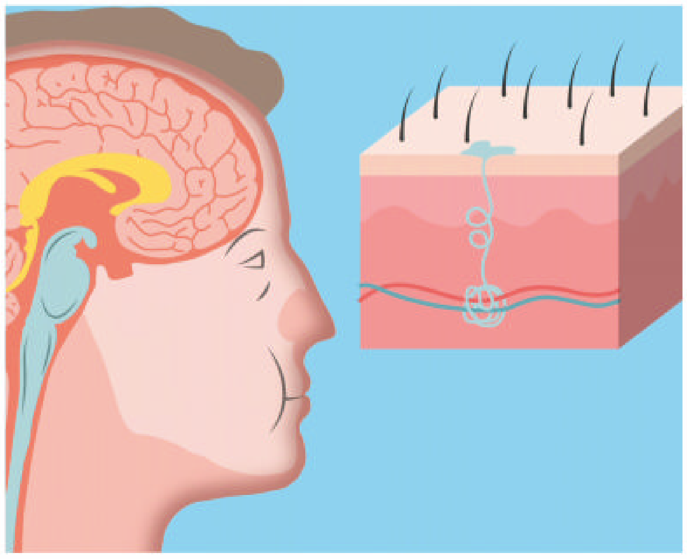
3 Pressure
Taking in a deep breath, the lungs inflate, causing the diaphragm to contract. This in turn increases the pressure applied to the stomach.



4 Prevention
Part of the larynx known as the glottis closes, preventing vomit from entering the lungs as it travels back up your oesophagus towards your mouth.

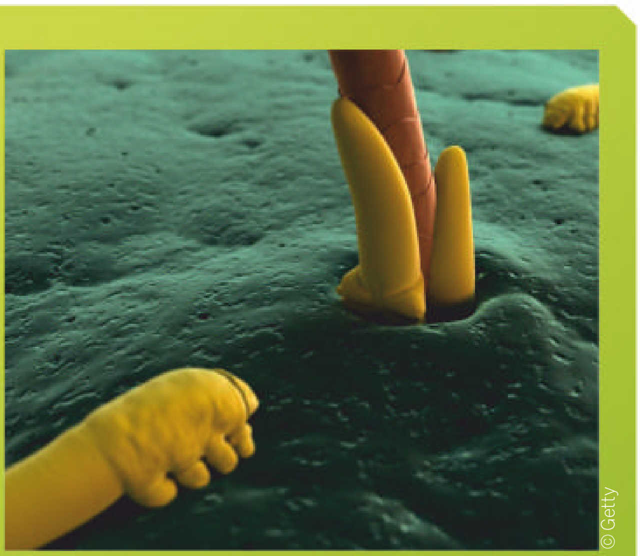


5 Contraction
In order for vomit to move upwards and out of your body your abdominal muscles contract and further increase pressure, and the sphincter at the base of the stomach closes so no vomit can travel downwards.



6 Sweating
As a result of the strenuous activity and stress of throwing up, your heart rate increases, raising your body temperature. To combat this sudden increase in temperature the body sweats to cool itself down.

© Illustration by Ed Crooks

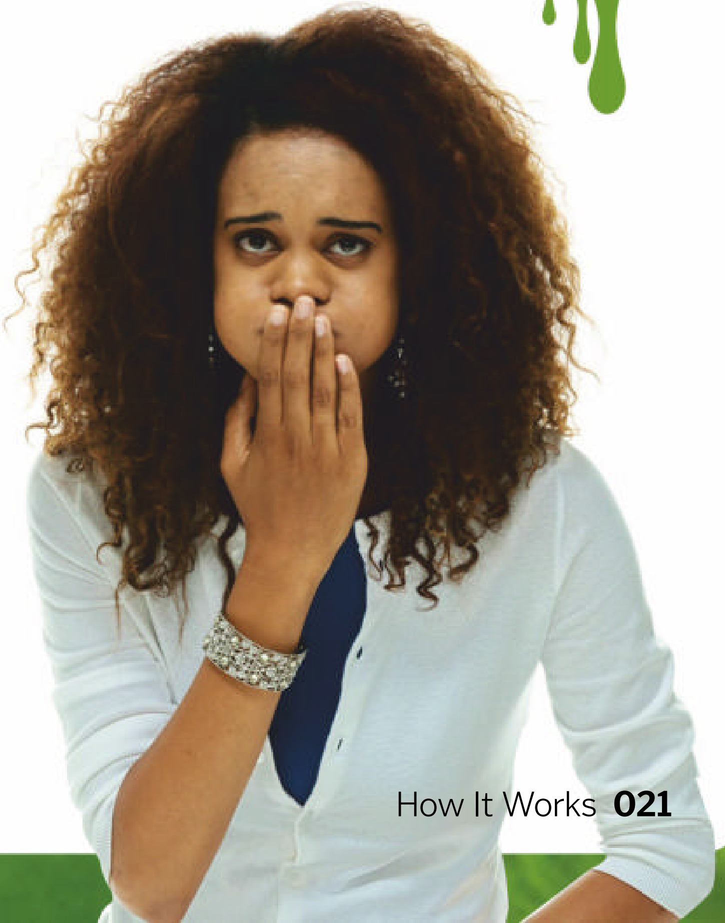


© Getty

Demodex folliculorum are microscopic mites that live within hair follicles on your face

3 MITES LIVE IN YOUR EYELASHES

The human body is a breeding ground for mites and bacteria. The majority, however, are harmless, even the ones in your eyelashes. Before you rush to the mirror to take a glimpse at the critters, they cannot be seen with the naked eye. Known as *Demodex folliculorum*, these microscopic face mites live in or around hair follicles, feeding on the dead skin cells and oil that has built up in the surrounding area. Typically causing no harm, in rare cases they may cause eye infections. Research has found that as we age the number of these tiny hitchhikers increases. As newborns humans are free from mite invasion. However, by the age of around 60 years, almost everyone is sure to have collected them along the way. It's still unclear as to how these mites reproduce, but what we do know is that they live for around 14 days, hatching and growing into adults in about seven days.



4 EAR WAX ISN'T MADE OF WAX

The scientific name for earwax is cerumen. Cerumen is a combination of sebum – essentially skin cells that have fallen off from inside the ear – bits of hair and secretions from the ceruminous glands in the outer ear canal. The consistency and colour may differ between people. Although often a yellow-brownish gooey build-up, in northeastern Asia in countries such as China, earwax appears as a more dry, pale and flaky substance. The role of this wax is to trap debris and bacteria within the ear channel, preventing it from damaging or infecting our invaluable eardrums.

In the US, using cotton buds to clean out ears causes more than 10,000 injuries a year

© Getty

5 BLACKHEADS AREN'T FILLED WITH DIRT

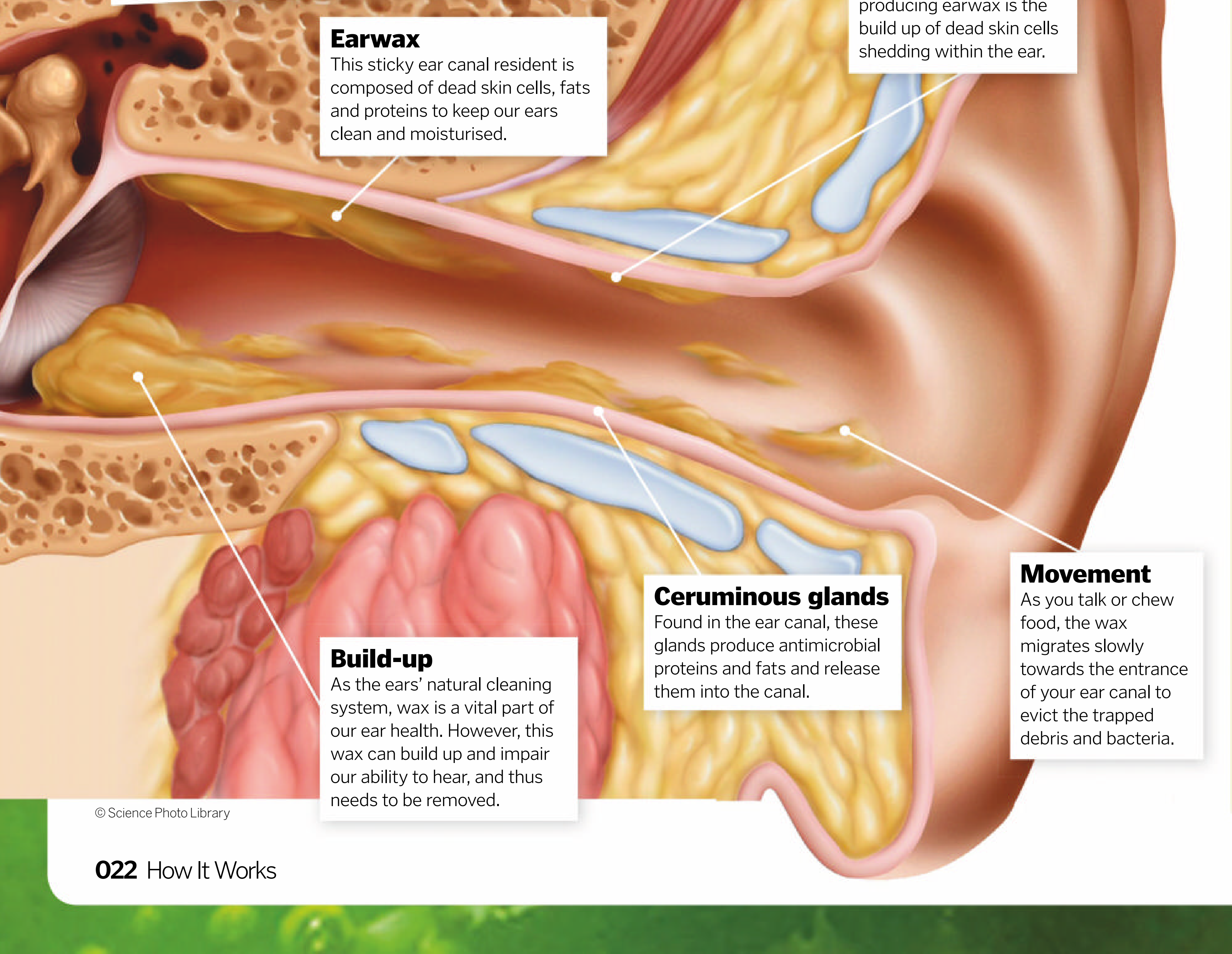
For all of those popaholics out there who enjoy watching online videos of blackhead and pimple extractions, you might be surprised to find out that it's a common misconception that blackheads are the result of dirt building up in the pores of our face. In the same way pimples form as a collection of dead skin cells beneath the skin, blackheads are made up of similar cells and an oily substance called sebum which is produced by the sebaceous glands of a hair follicle. When exposed to the air at the surface of the skin, surrounding oxygen oxidises the sebum, turning it black.

© Alamy

In the US, acne affects up to 50 million people

Digging into earwax

What makes the goo within our ears?



Dead cells
One vital ingredient in producing earwax is the build up of dead skin cells shedding within the ear.

Earwax
This sticky ear canal resident is composed of dead skin cells, fats and proteins to keep our ears clean and moisturised.

Ceruminous glands
Found in the ear canal, these glands produce antimicrobial proteins and fats and release them into the canal.

Movement
As you talk or chew food, the wax migrates slowly towards the entrance of your ear canal to evict the trapped debris and bacteria.

Build-up
As the ears' natural cleaning system, wax is a vital part of our ear health. However, this wax can build up and impair our ability to hear, and thus needs to be removed.

© Science Photo Library

6 WHAT THE COLOUR OF YOUR SNOT SAYS ABOUT YOU

○ 1 **Clear**
Boogers are made up of water and a protein called mucin, which together form a clear gelatinous substance, indicating you're healthy.

○ 2 **White**
When you've got a viral infection, clear mucin builds in the sinuses, and may turn a milky white colour.

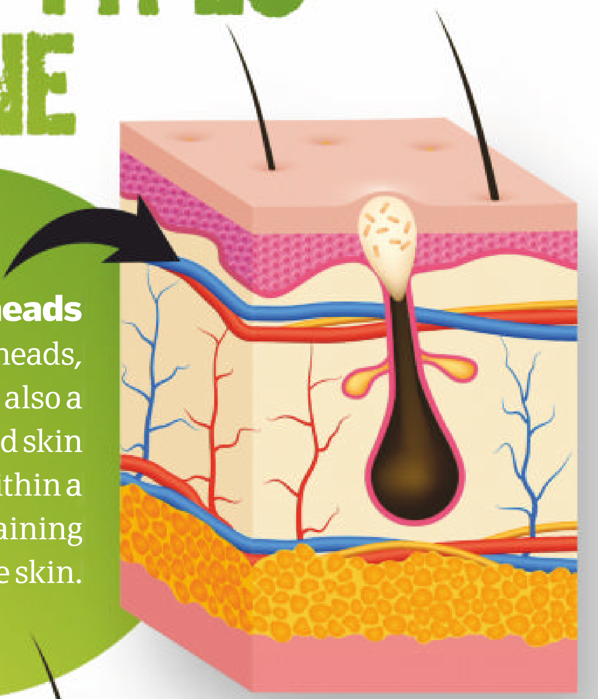
● 3 **Yellow/green**
If your snot's turned green or yellow it's a sure sign you're developing a cold. This colour comes from the build up of dead white blood cells used to fight infection.

● 4 **Brown/orange**
Blowing your nose and seeing brown or orange might have you concerned, but it's likely just dried blood.

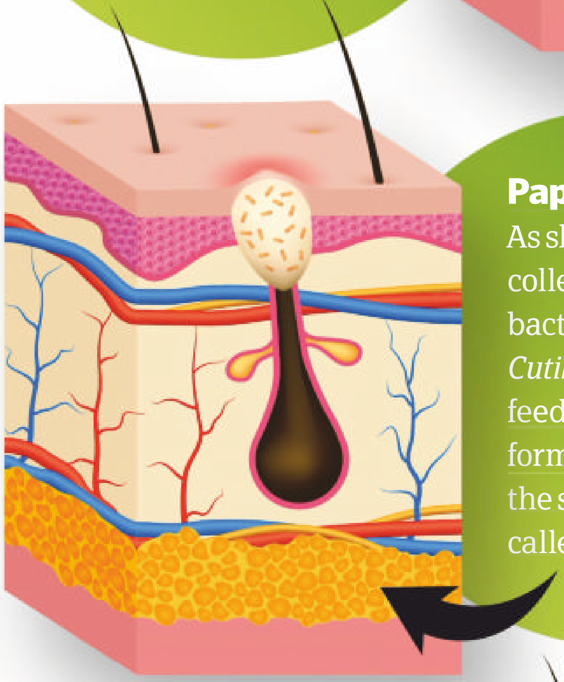
● 5 **Black**
Inhaling pollutants such as smoke or dust could result in some black snot, but it may also be a sign of a fungal infection.

DID YOU KNOW? ⑦ *The largest organism in the world is a fungus, Armillaria ostoyae, occupying 2,385 acres*

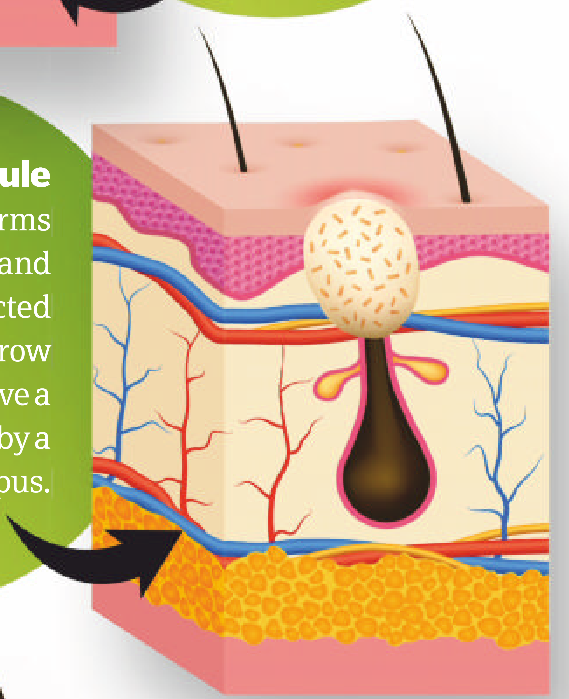
OTHER TYPES OF ACNE



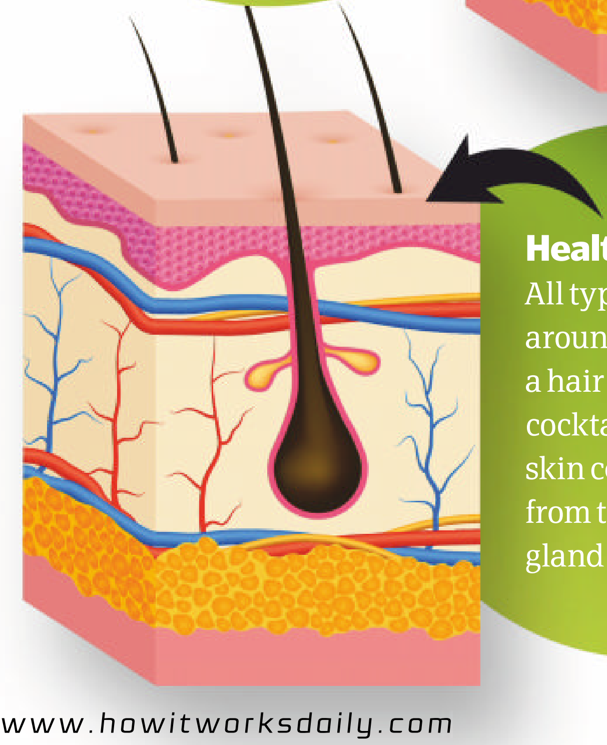
Whiteheads
Similar to blackheads, whiteheads are also a collection of dead skin cells collecting within a hair follicle, remaining under the skin.



Papule
As skin cells and oil collect in the follicle a bacteria called *Cutibacterium acnes* feeds on the cells, forming a red lump on the skin's surface called a comedone.



Pustule
This type of acne forms when the collecting oil and skin cells become infected and continue to grow under the skin. The have a white centre, caused by a build-up of pus.



Healthy
All types of acne form around the location of a hair follicle where a cocktail of oil and skin cells secreted from the sebaceous gland may build up.

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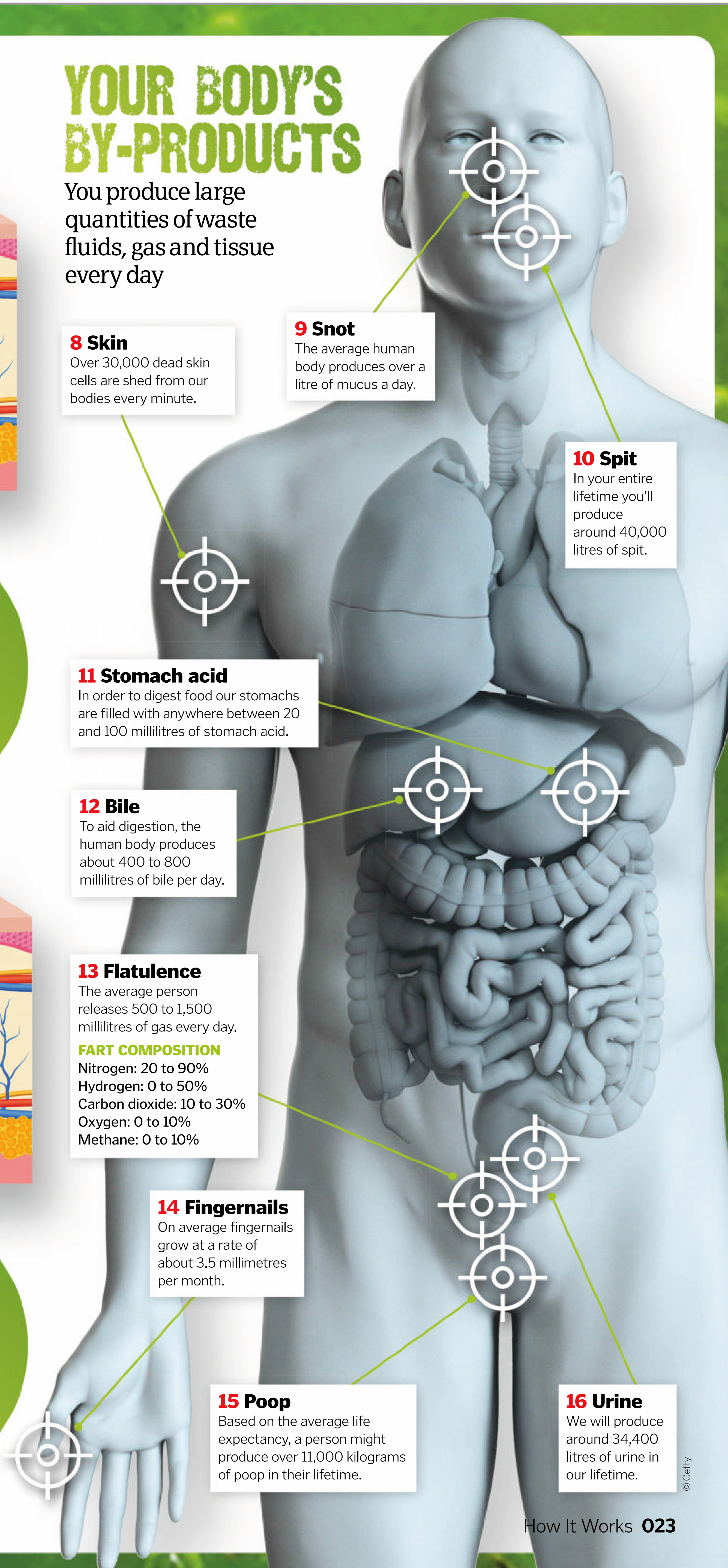
YOUR BODY'S BY-PRODUCTS

You produce large quantities of waste fluids, gas and tissue every day



8 Skin
Over 30,000 dead skin cells are shed from our bodies every minute.

9 Snot
The average human body produces over a litre of mucus a day.

10 Spit
In your entire lifetime you'll produce around 40,000 litres of spit.

11 Stomach acid
In order to digest food our stomachs are filled with anywhere between 20 and 100 millilitres of stomach acid.

12 Bile
To aid digestion, the human body produces about 400 to 800 millilitres of bile per day.

13 Flatulence
The average person releases 500 to 1,500 millilitres of gas every day.

FART COMPOSITION

Nitrogen: 20 to 90%
Hydrogen: 0 to 50%
Carbon dioxide: 10 to 30%
Oxygen: 0 to 10%
Methane: 0 to 10%

14 Fingernails
On average fingernails grow at a rate of about 3.5 millimetres per month.

15 Poop
Based on the average life expectancy, a person might produce over 11,000 kilograms of poop in their lifetime.

16 Urine
We will produce around 34,400 litres of urine in our lifetime.

© Getty

The poo you flush down the toilet is used to power the plant that processes it

© Getty

17 POOP IS USED TO POWER TREATMENT PLANTS

Once it's sent swirling down the toilet, human waste embarks upon a recycling journey that might see it end up back on your plate. The first stage of turning poop into power is filtration. Passing through filters and sieves in our sewage system, organic waste is separated from larger materials such as wipes, sanitary products and even oil. Continuing on to holding tanks, this slurry of waste and water is then stirred to allow 'flocs' to form, whereby poo particles clump together and fall to the tank floor. Removing the majority of water for separate treatment, the remaining sludge is heated to completely dry out. Anaerobic bacteria is then added to biologically break down waste, and as a result high levels of methane gas are produced. As a highly flammable gas, methane is collected and burnt to produce electricity, enough to power the treatment plant that processes the waste. Once broken down, the remaining dried waste is sent to the agricultural industry to be used as fertiliser. So the next time you're tucking into your homemade salad, there is a chance you helped to grow the ingredients.

18 'FATBERGS' ARE CLOGGING THE SEWERS

Deep beneath the streets of London and around the world, floating islands of rubbish have begun to form, dubbed fatbergs. Building up along our sewage systems, piles of wipes, oil and grease are morphed into monstrous mounds of waste which are hard to shift. As they collect, litres of congealed oil and conglomerated wet wipes pile together to form these giant blockages, some as heavy as a blue whale. Back in 2017 one fatberg hit the headlines as one of the largest yet to be broken down. It took eight workers using high-pressure jet hoses nine weeks to remove. Commonly occurring in various sizes, Goliath fatbergs are becoming more and more common – just last year a 90-tonne blockage was uncovered in Liverpool spanning 84 metres.

The vast London fatberg

As one of the largest sewage system blockages discovered, this fatberg astonished people back in 2017

Length:
250 metres
11 double-decker buses
Tower Bridge: 244 metres long
Space Needle: 184 metres tall

Weight:
130 tonnes
19 African elephants
International Space Station: 419.7 tonnes

© Getty

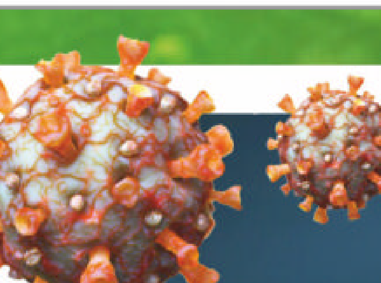
93 per cent of sewage blockages are caused by built-up wet wipes

© Getty

DID YOU KNOW? ⑲ *The average person flushes around 145 kilograms of poop each year*

Once opened, milk lasts five to seven days

© Alamy



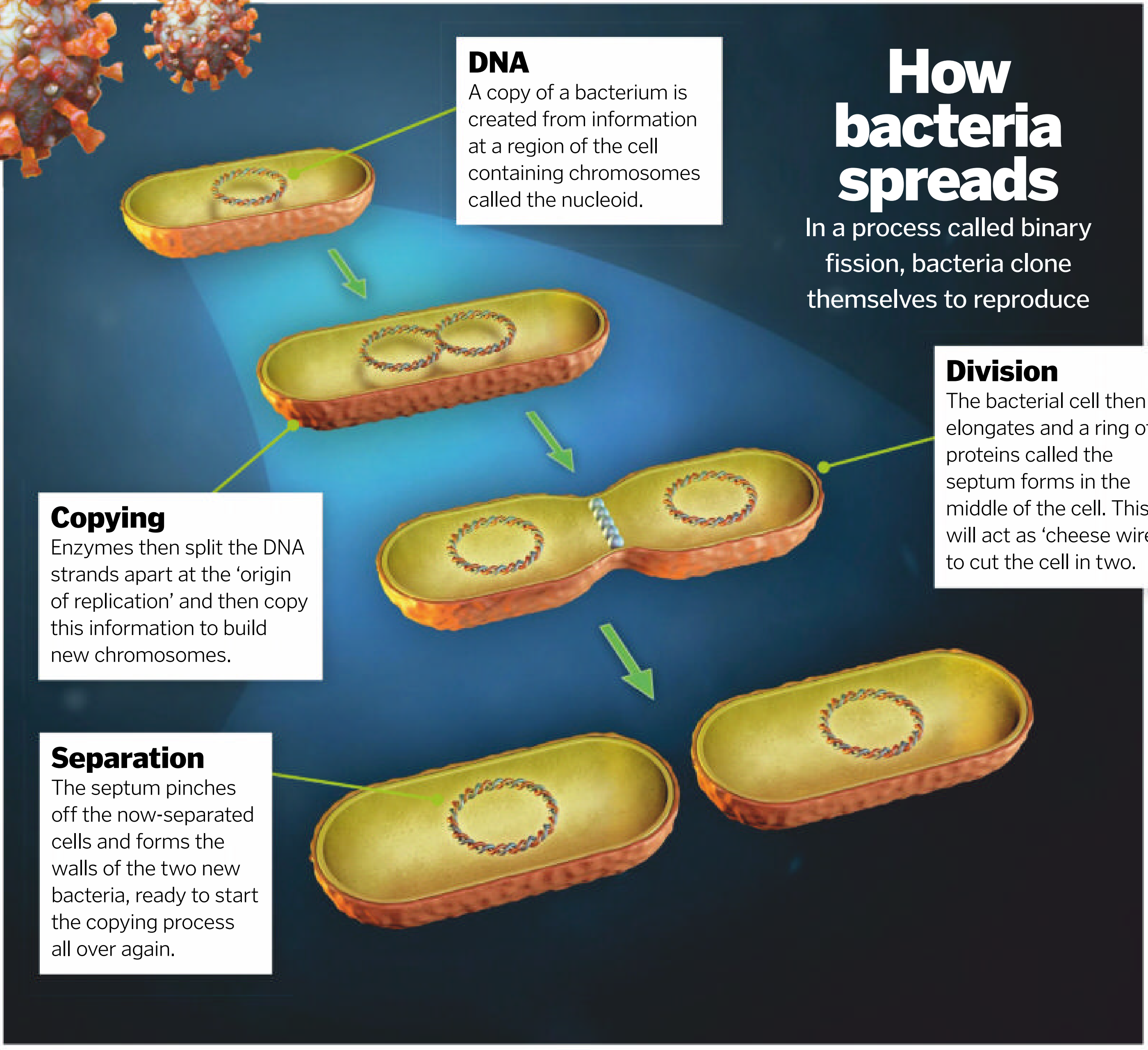
20 BACTERIA CAUSES MILK TO CURDLE

It's the worst way to start the day when you unknowingly pour the coagulated lumps of gone-off milk into a freshly brewed tea. Milk is predominantly made up of proteins, sugars and fat, but it's the proteins that give the milk its colour and texture. In fresh milk these protein molecules repel one another, almost in the same way the matching poles of two magnets would. However, when the pH of the milk is lowered, the protein molecules begin to attract one another and clump together. This happens when the naturally occurring bacteria within the milk begin to multiply and feast on the milk's sugar content, releasing acids that lower the milk's pH.

This build-up of acid also results in the sour taste some of us may have unwittingly experienced when drinking from the bottle.

How bacteria spreads

In a process called binary fission, bacteria clone themselves to reproduce



DNA
A copy of a bacterium is created from information at a region of the cell containing chromosomes called the nucleoid.

Copying
Enzymes then split the DNA strands apart at the 'origin of replication' and then copy this information to build new chromosomes.

Division
The bacterial cell then elongates and a ring of proteins called the septum forms in the middle of the cell. This will act as 'cheese wire' to cut the cell in two.

Separation
The septum pinches off the now-separated cells and forms the walls of the two new bacteria, ready to start the copying process all over again.

© Alamy

BACTERIA BASICS

100x
Bacteria can travel a lot further than the length of their body in a second

2 micrometres
On average bacteria are incredibly small at 1/500 of a millimetre

7 in 10
Most kitchen fridges are home to harmful bacteria

3.5 billion years old
Bacteria are the longest living organisms on Earth

approx. 67
Our belly buttons are home to a wealth of bacterial species

10x
A mobile phone carries more bacteria than a toilet

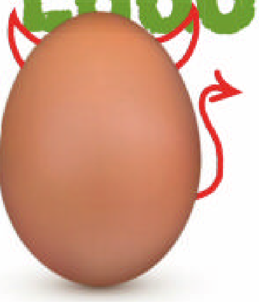
2,097,152
Escherichia coli can split and multiply every 20 minutes, over seven hours that's a lot copies

100 MILLION
Your toothbrush is filled with millions of types of bacteria

1%
Only a small proportion of bacteria species on Earth can make you ill

4 to 60 degrees Celsius
Bacteria have an excellent tolerance to heat in order to survive

21 AMERICAN EGGS ARE WASHED WITH SOAP



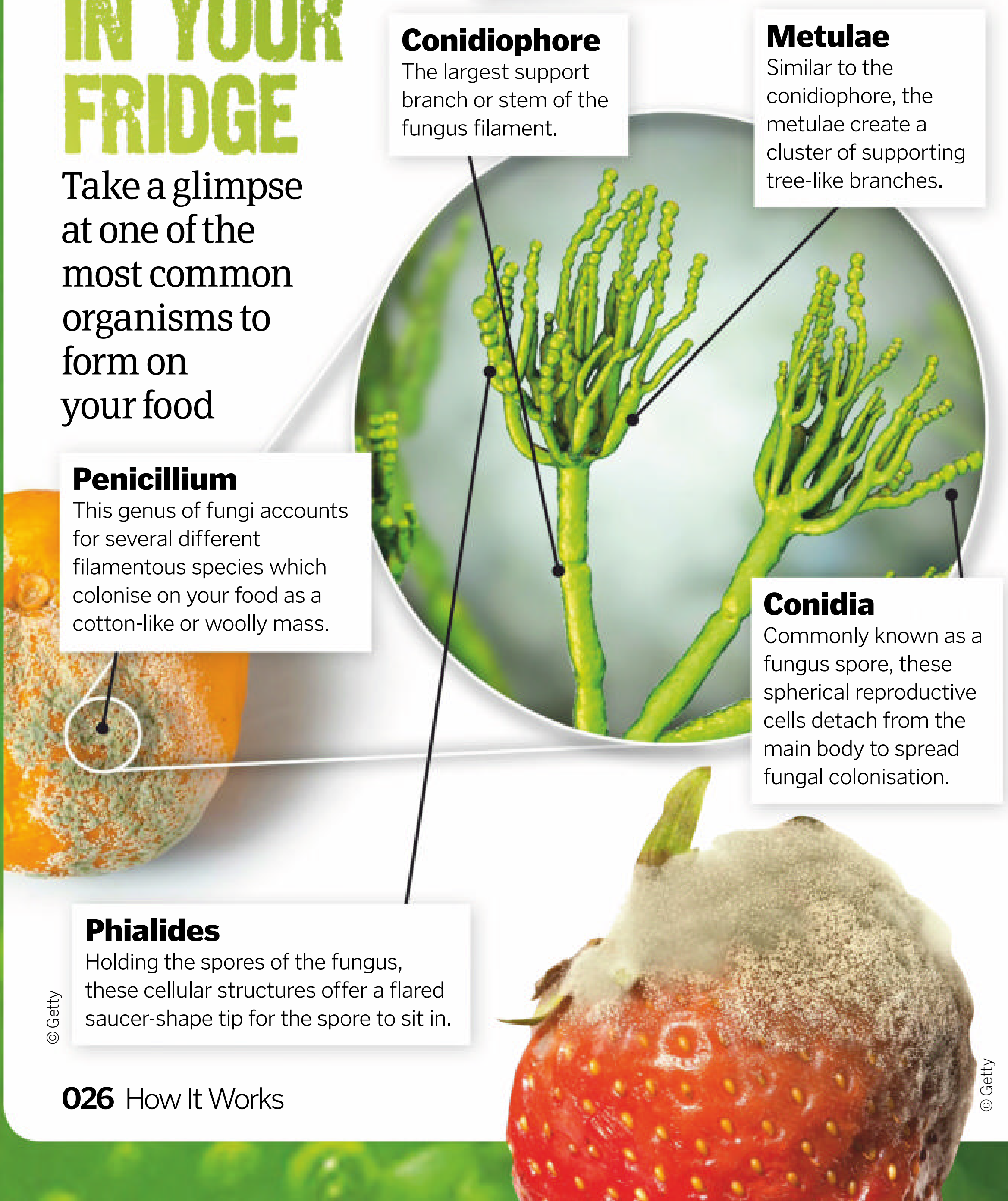
Have you ever wondered why countries like America and Japan have to refrigerate their eggs, while European countries are happy to leave them on the shelf? The answer lies in their attempt to prevent salmonella bacteria from causing illness and even death to those that consume eggs. The bacteria works by infiltrating the porous shell of the egg and feasting on the yolk and albumen within. Where hens are kept in close quarters on a large scale, often in caged environments, salmonella can quickly spread. In countries such as America, eggs are washed in either soap, enzymes or chlorine to remove any risk of bacterial contamination. However, stripping away the risk of salmonella infection also strips away a cuticle coating naturally produced as a physical barrier to protect the egg within from infection, as well as keeping moisture inside. By removing this cuticle, the egg is susceptible to bacterial invasion if not immediately refrigerated until cooking.

Without a thin protective layer, washed eggs must remain chilled to prevent bacteria spreading

© Getty

23 FUNGI GROWS IN YOUR FRIDGE

Take a glimpse at one of the most common organisms to form on your food



Conidiophore
The largest support branch or stem of the fungus filament.

Metulae
Similar to the conidiophore, the metulae create a cluster of supporting tree-like branches.

Penicillium
This genus of fungi accounts for several different filamentous species which colonise on your food as a cotton-like or woolly mass.

Conidia
Commonly known as a fungus spore, these spherical reproductive cells detach from the main body to spread fungal colonisation.

Phialides
Holding the spores of the fungus, these cellular structures offer a flared saucer-shape tip for the spore to sit in.

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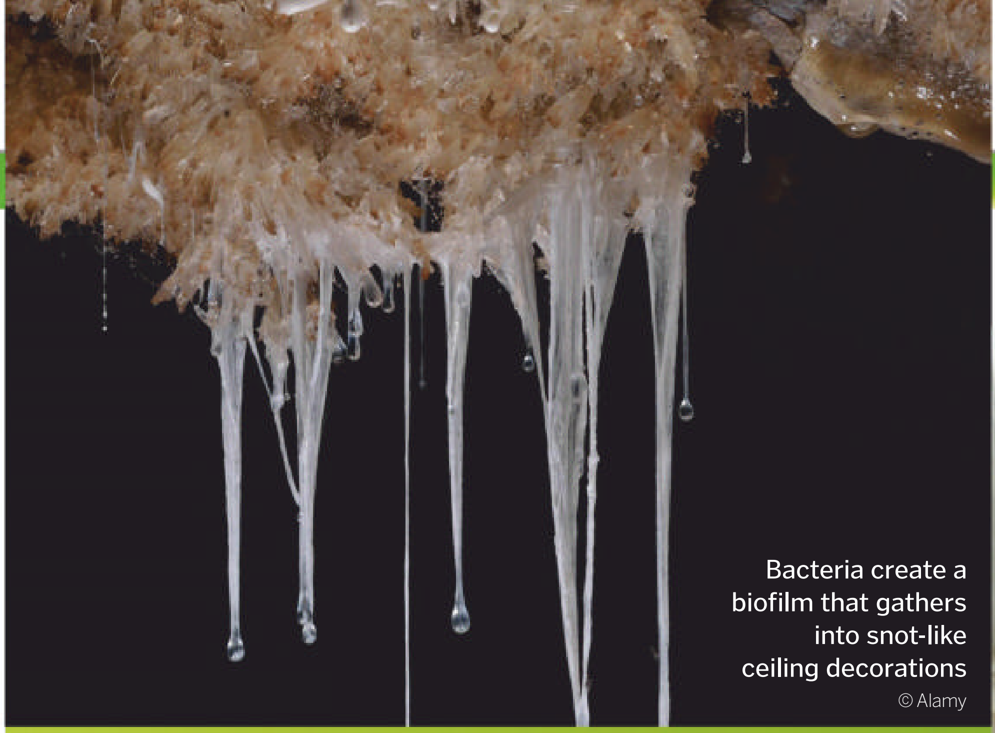


Bacteria create a biofilm that gathers into snot-like ceiling decorations

© Alamy

22 'SNOTTITES' HANG IN THIS CAVE THAT SMELLS LIKE EGGS

Known as Sulphur Cave Spring, this cavern in Colorado is teeming with toxic gases, covered in blood-red worms and dripping in bacteria. Emitting a stench of rotten eggs, this cave gets its name from the high levels of sulphur stored within. Vented from deep below Earth's surface, hydrogen sulphide and carbon dioxide fill the cave, making it potentially deadly for anyone that enters. However, quite strangely, life is thriving within. Blood worms are one of the abundant cave dwellers, feasting on the bountiful amounts of bacteria that line the cave walls. It's believed the worms obtain their colour thanks to high haemoglobin levels in their bodies as a defence against the deadly sulphur gas. The high temperatures and humidity within the cave make a perfect breeding ground for bacteria, so much so that oozing from the ceiling are slimy structures known as 'snottites', formed over time as bacteria have grown into mucus-like structures.

24 HONEY IS BEE BARF, BUT NOT AS WE KNOW IT

You may have heard that the sweet breakfast condiment is the result of a bee with a bad stomach, vomiting its guts and storing the sugary expulsion. However, it's not barf as we know it. Rather than entering the bee's stomach, called the ventriculus, bees are equipped with an internal sac known as a crop or honey stomach for storage. Upon returning to the hive, these filled honey sacs are emptied into the mouths of processor bees, who will fill honeycombs for storage. In the process of transferring nectar from one bee to another, the enzymes in the crop alter the pH and composition of the nectar to prevent it from spoiling. The bees then use their wings to fan the honey to reduce the amount of water. Once this stage is complete the bees then secrete a liquid which will harden and form the beeswax seal to trap the honey inside the honeycomb.

A single hive can produce up to 27 kilograms of honey per season

© Getty

DID YOU KNOW? ㉕ The study of farts and other internal gases is called flatology

© Getty

26 SILK IS MADE FROM WORM SALIVA

It's one of the most desirable fabric materials, accounting for only 0.2 per cent of the global fibre market, but did you know silk is spun from the saliva of silkworms? *Bombyx mori*, or domestic silk moths, are the biological factories used in silk production. As caterpillars, when they are ready to transform into their adult moth bodies, they spin cocoons made from a sticky protein called fibroin and a bonding agent called sericin from their salivary glands in the mouth. Winding the threads around themselves, the strands harden in contact with the air to create their metamorphic shell. This is where the fibre extraction comes in. To obtain raw silk, these cocoons are typically boiled to kill the developing moth inside and to soften the hardened cocoon and break down the binding sericin. The protein fibres can then be pulled and spun by workers to create threads used in fabric production. It takes around 6,600 silkworms to make just one kilogram of silk.

© Getty

Silkworm cocoons are boiled to soften the threads and kill the worm within

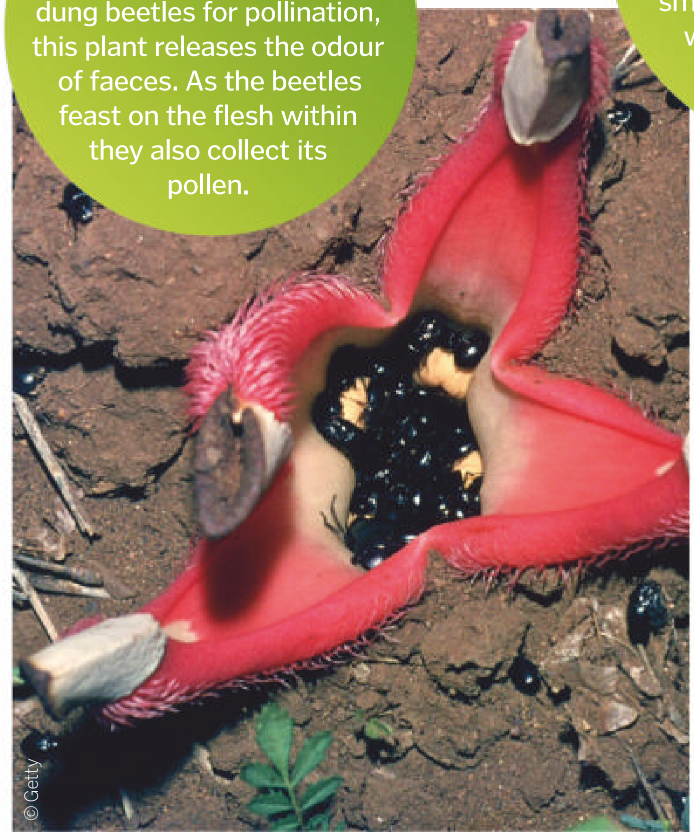
FACTS ABOUT THE WORLD'S SMELLIEST PLANTS

© Getty

27

Skunk cabbage

As the name suggests, this plant is well known for its pungent, unpleasant smell, which wards off unwanted predators and attracts insect pollinators.


© Getty

28

Jackal food

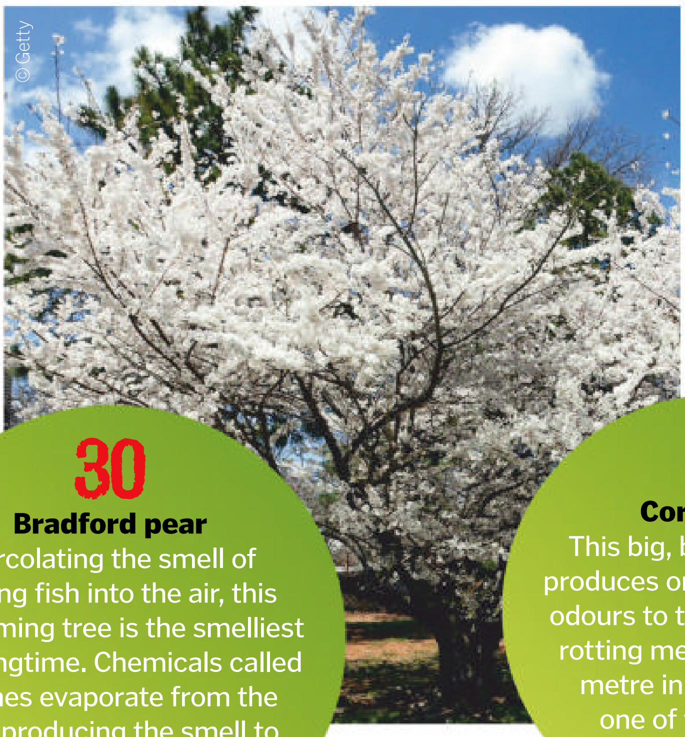
In an attempt to attract dung beetles for pollination, this plant releases the odour of faeces. As the beetles feast on the flesh within they also collect its pollen.

© Getty

29

Titan arum

Blooming for just 48 hours, this behemoth of a plant has been branded the smelliest plant on Earth, wafting the scent of rotting flesh into the air.


© Getty

30

Bradford pear

Percolating the smell of rotting fish into the air, this blossoming tree is the smelliest of springtime. Chemicals called amines evaporate from the tree, producing the smell to attract insects for pollination.

© Getty

31

Corpse lily

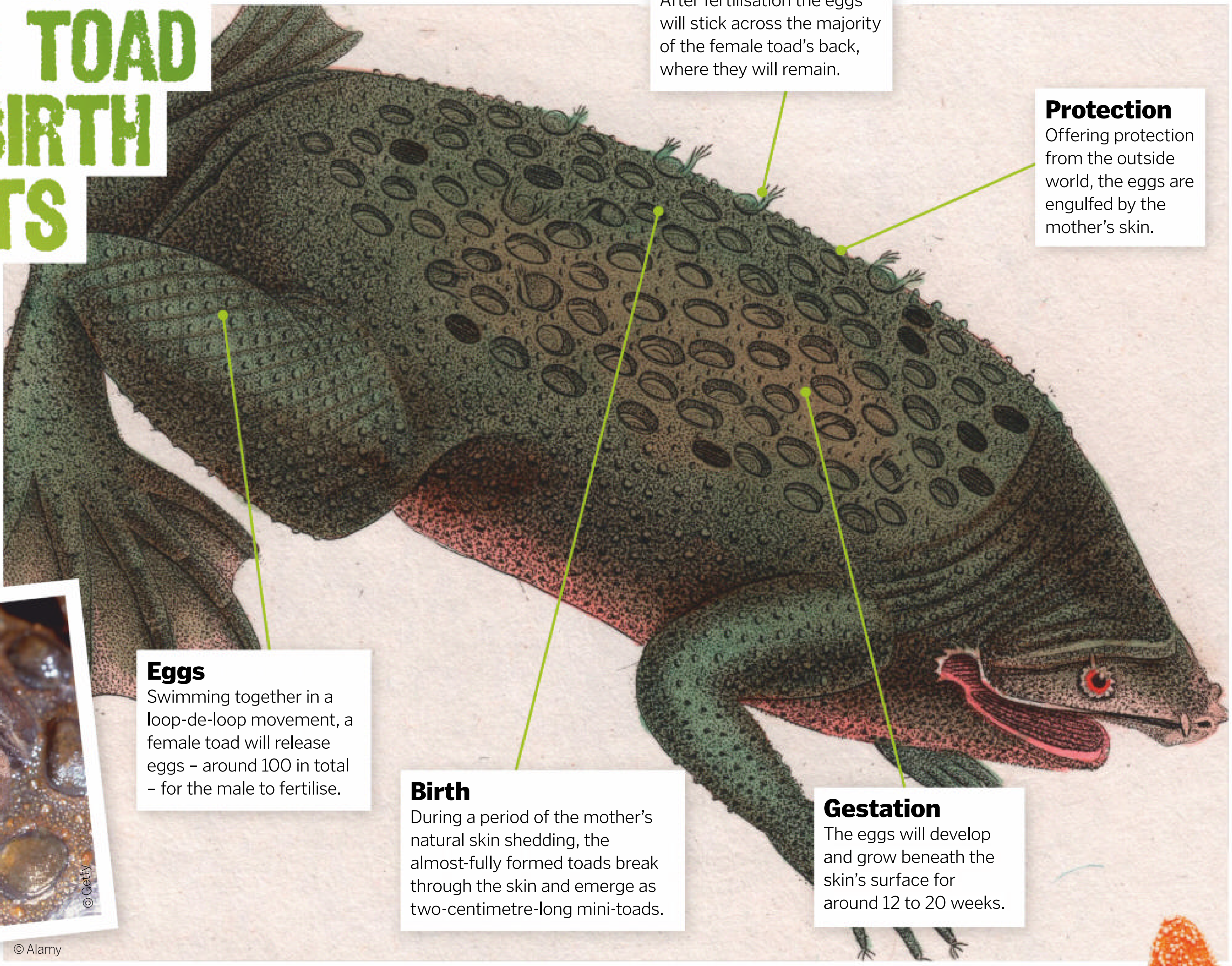
This big, beautiful plant produces one of the foulest odours to the human nose: rotting meat. Around one metre in width, this is one of the biggest, smelliest plants.

32 THIS TOAD GIVES BIRTH FROM ITS BACK

Meet the Surinam toad mother that carries its babies on its back before they burst free

The babies emerge from bubbles on the skin

© Getty



Fertilisation
After fertilisation the eggs will stick across the majority of the female toad's back, where they will remain.

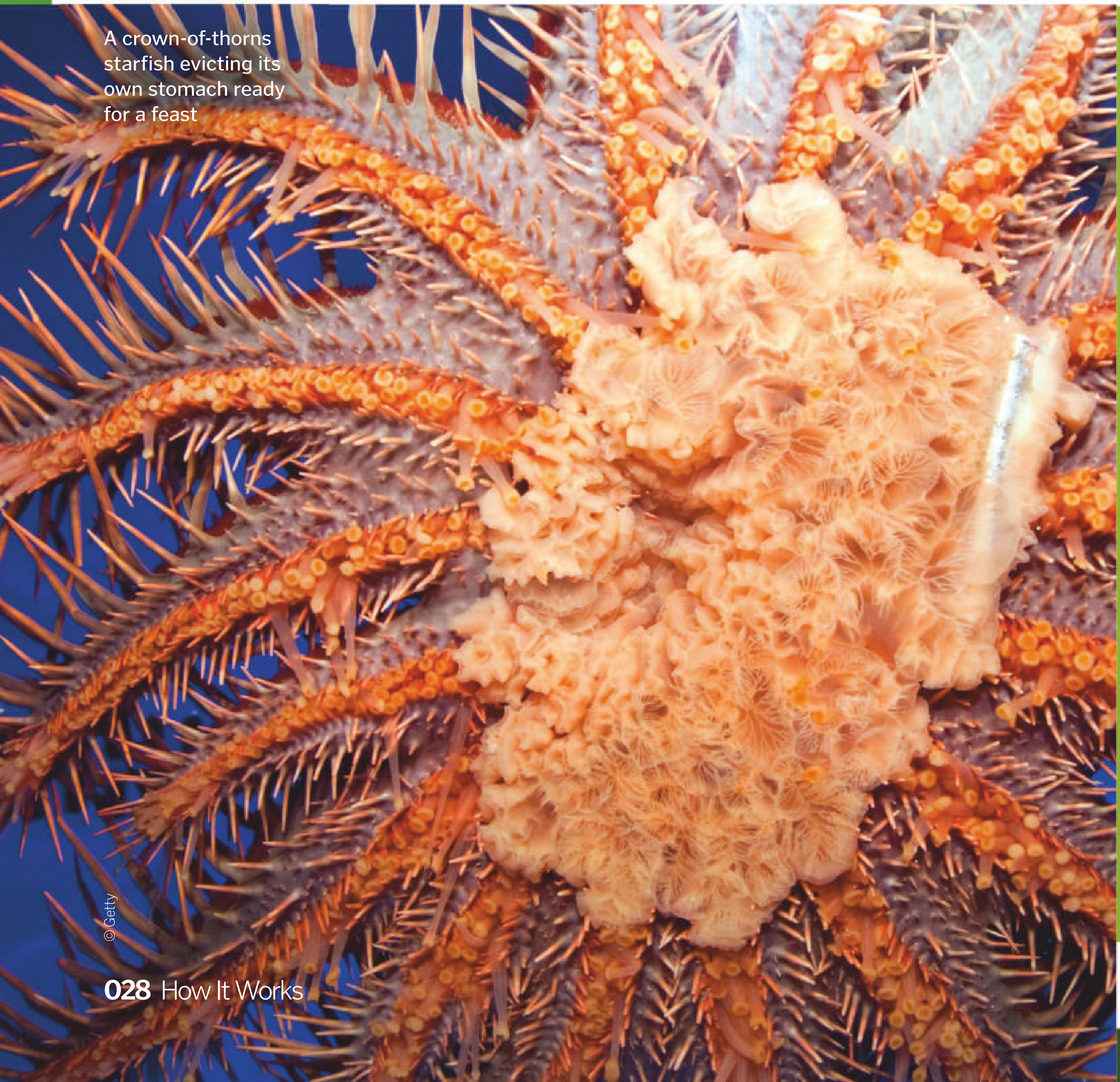
Protection
Offering protection from the outside world, the eggs are engulfed by the mother's skin.

Eggs
Swimming together in a loop-de-loop movement, a female toad will release eggs – around 100 in total – for the male to fertilise.

Birth
During a period of the mother's natural skin shedding, the almost-fully formed toads break through the skin and emerge as two-centimetre-long mini-toads.

Gestation
The eggs will develop and grow beneath the skin's surface for around 12 to 20 weeks.

© Alamy



A crown-of-thorns starfish evicting its own stomach ready for a feast

© Getty

33 STARFISH EJECT THEIR OWN STOMACHS TO EAT

© Getty

Travelling at 15 centimetres per minute starfish are some of the slowest moving creatures in the ocean. So how do they munch down a meal along the way? Without any razor-sharp teeth or claws to grasp their food, starfish have evolved a unique way to capture their prey that still makes them a deadly predator. Striking fear into the hearts of corals, clams and oysters alike, starfish deploy their own stomach to engulf and digest their food. Extending out through their mouths, their stomach absorbs their prey while a digestive enzyme begins to break down the food. Now a seafood soup, the liquidised prey and the stomach are then retracted back via the mouth, and digestion continues in their ten digestive glands.

DID YOU KNOW? ㉞ One in 1,000 people are unable to smell the stench of skunk spray

35 SKUNKS CAN SPRAY UP TO THREE METRES

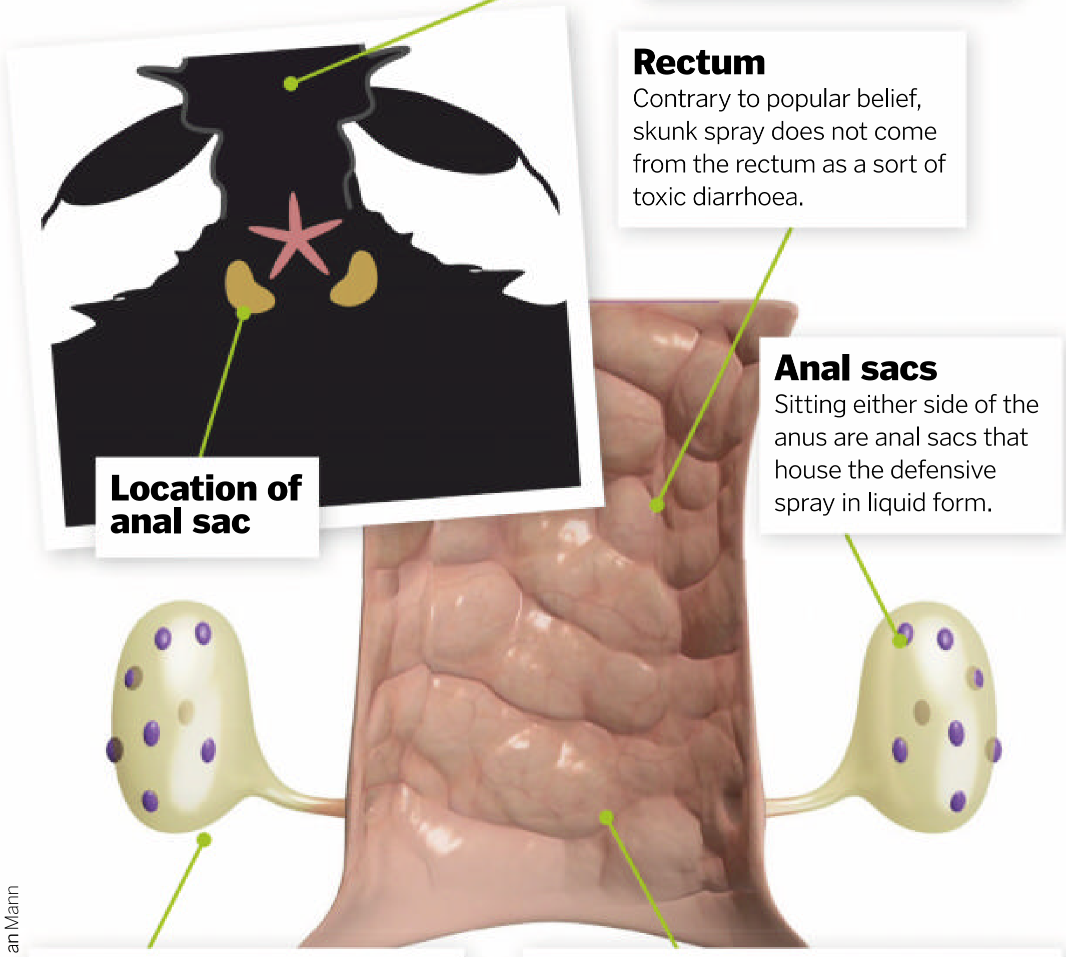
© Getty

Untreated, the smell of skunk spray can last 14 to 21 days

Well known for their stinky defence mechanism, skunks strike fear into the hearts of their adversaries due to their ability to spray a pungent chemical compound from their behinds. It's a gross defence system that is highly effective in warding off predators. When threatened these black-and-white beasts puff up their bodies and stomp, raising their tails as a countdown to them launching a non-toxic but foul-smelling liquid containing compounds of thiols. This defence is thought to be a skunk's last resort, as it takes around ten days to refill the internal sacs carrying the liquid. Due to its high sulphur content this liquid presents a smell reminiscent of rotten eggs so strong it has been known to cause human eyes to water, noses to run and even cause vomiting.

How does a skunk spray?

The mechanics behind this pungent defence mechanism



Tail
A skunk will lift this away from the anal glands for optimal shooting and reducing the risk of getting any in its fur.

Rectum
Contrary to popular belief, skunk spray does not come from the rectum as a sort of toxic diarrhoea.

Anal sacs
Sitting either side of the anus are anal sacs that house the defensive spray in liquid form.

Location of anal sac

Long lasting
Once sprayed this volatile cocktail of chemicals can persist on skin and hair for around three to four days.

Projection
Using the anal muscles, the anal glands are tightly squeezed to force the liquid out through nipple-like protrusions near the anus.

© Illustration by Adrian Mann

FACTS ABOUT GROSS ANIMAL DEFENCES

© Alamy

36 Horned lizard

When faced with a predatory threat, horned lizards will intentionally rupture thin blood vessels surrounding the eyes, firing a stream of foul-tasting blood almost a metre towards their adversaries.

© Alamy

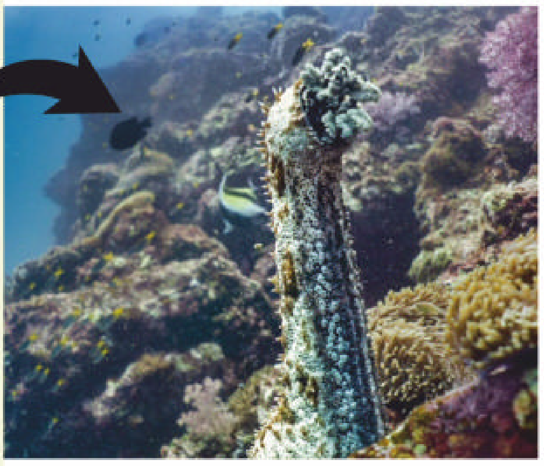
37 Hagfish

Playing with slime might seem like a fun pastime, but for the hagfish it's the best defence against predators. When threatened these eel-like invertebrates release a gelatinous slime into the water in the hope of smothering the gills of approaching fish.

© Alamy

38 Spanish ribbed newt

At first glance this smooth-bodied newt might appear to be lacking in the natural defence department. However, when under attack this newt will puff out its body so fiercely the poisonous spines of its ribs will puncture its own skin as defensive barbs.


© Getty

39 Sea cucumber

Some species of sea cucumber have come up with an unusual technique for self preservation: if you can't fight them off, simply eject your vital organs from your body and grow new ones, leaving the predator to feast on the old organs.

40 Exploding ants

When all else fails, if a predator's going to take you down, why not take them down with you. This is the attitude of the exploding ants in Borneo. When salvation is out of sight, these ants erupt their own bodies with a curry-scented toxin, fatal to invading predators.

Source: Wiki Commons/© Bernard Dupont

HOW OPTICAL ILLUSIONS WORK

Why do our eyes play tricks on our brain?

Words by
Ailsa Harvey

Literal optical illusions

These creations have more than one reality

Some people say that seeing is believing. We expect what we see to exist. When we look at what's in front of our eyes, each scene comes with masses of information. What do the shapes mean and how do they connect? To make sense of the world around us, we rely on our eyes to provide our brains with accurate visual information – but sometimes our eyes can deceive us.

Optical illusions make you see things which aren't physically there, give motion to shapes that are static and can even make something impossible seem real. Split into three main categories – literal, physiological and cognitive – each has a distinctive way of producing these mystical marvels. Not merely entertaining out-of-the-ordinary spectacles, visual illusions provide insight into the vital science behind eye-brain interactions.

For many of these visual wonders, you need to approach them with some existing knowledge. Take the title of this article as an example. You would have known immediately that you were reading about optical illusions. But how? Illusions can be incorporated into text as well as images. To someone unfamiliar with the shape of letters or the English alphabet, these blocks and shapes would hold no other meaning. For your brain to receive the information, it analysed the shapes and compared them to the knowledge stored in your memory, reading the shapes as letters. Focusing your attention solely on the blocks themselves would leave you with a meaningless pattern. The following illusions will put your eyes and brain to the test. What will your brain be able to comprehend and how will your eyes throw it off track?

Hidden faces

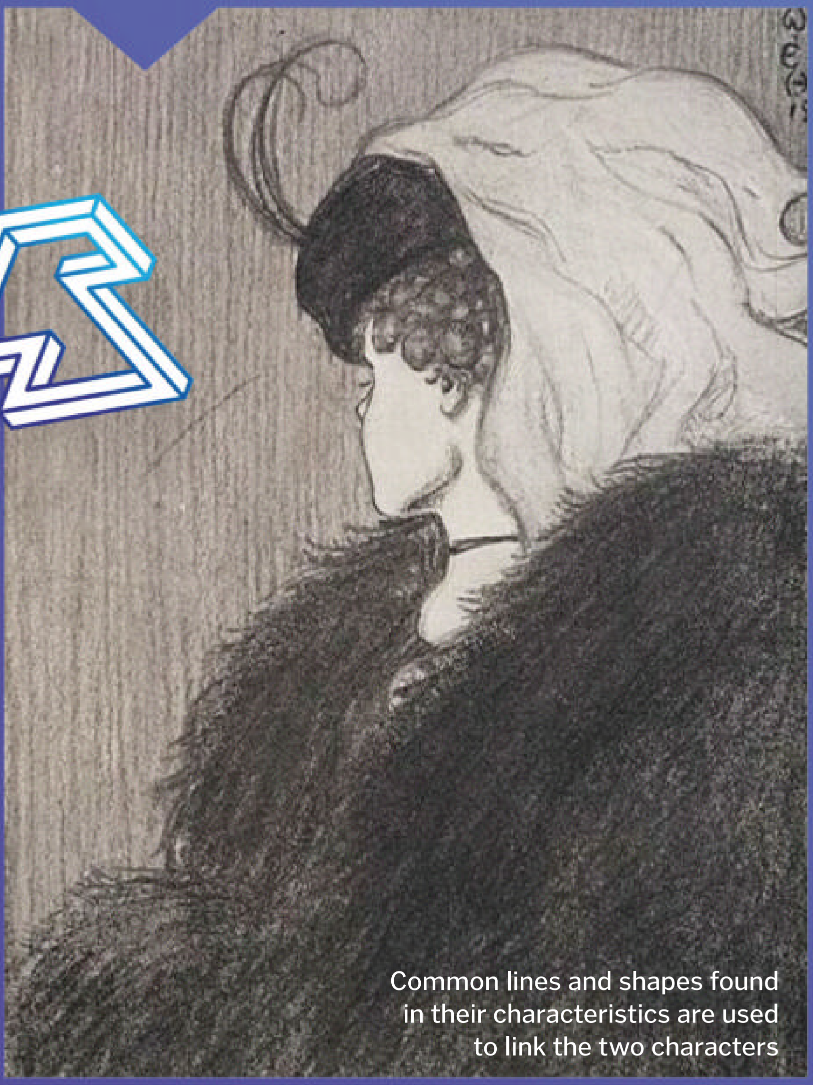
Deception isn't always carefully planned. Sometimes nature and the everyday muddle your brain too. Nature's unique shapes and forms can cause you to find new and unusual variations around every unexplored corner. Within the bark of this tree, the growths and dents reveal an imposter. Immediately your eyes are drawn to the shape of a face at the centre, highlighted by the light covering of moss. Your brain is familiar with the form of a human face, as you are likely to see many of them as you go about each day. When presented with this tree, while it is only a tree and not literally a face, your brain recognises both, and it will struggle not to see this familiar fat-lipped figure every time you glance back.

How your brain is tricked

When you look at this work of art, you will notice a person. But what does that person look like? Entitled 'My Wife and my Mother-in-Law', this drawing by American cartoonist William Ely Hill captures both the characters in its title at once. Depending on which section your eyes examine first, you will either be drawn to the young or old woman.

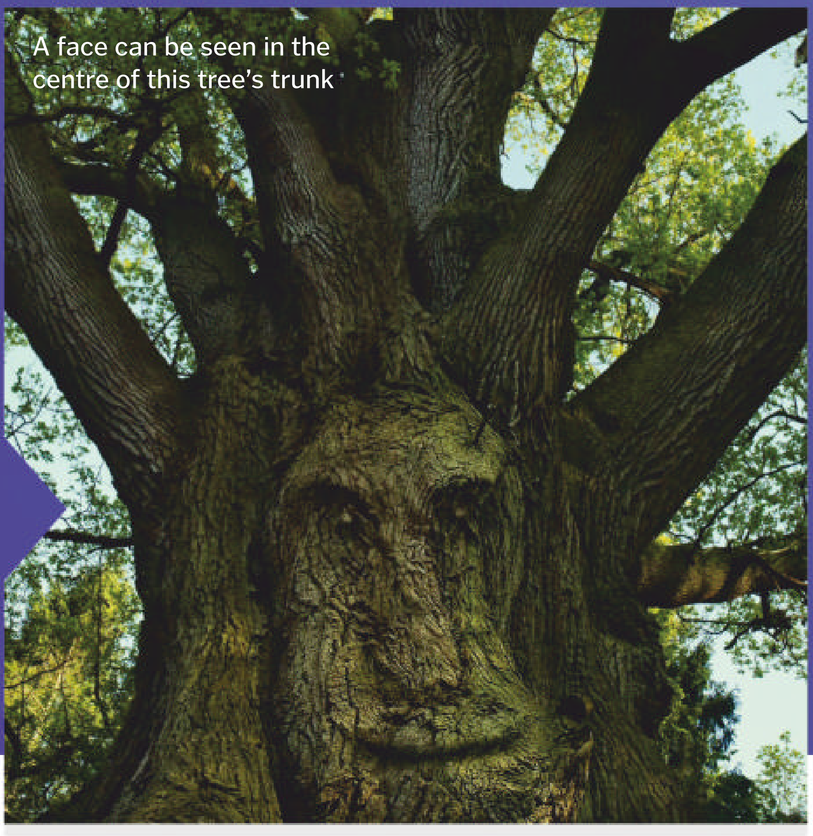
Some psychologists have concluded that if you are younger you are more likely to notice the young woman first, while if you are older you will notice the old, possibly due to people spending more time around others close in age. When your brain is trying to quickly make sense of what you are viewing, it will create familiar shapes and objects, and the woman in that category will be seen first.

If you are still struggling to work out where the other woman is, the old woman's mouth doubles up as the young woman's necklace, while the young woman's chin and jawline make up the old woman's large, pointy nose.



Common lines and shapes found in their characteristics are used to link the two characters

© William Ely Hill



A face can be seen in the centre of this tree's trunk

© Getty

THE PROCESS

1 OBSERVE IMAGE
When presented with the image, your eyes will quickly scan it, relaying the visual information to the brain.

2 ANALYSE SECTIONS
The brain then chooses which section and shapes to focus on. This choice will determine how you perceive the image.

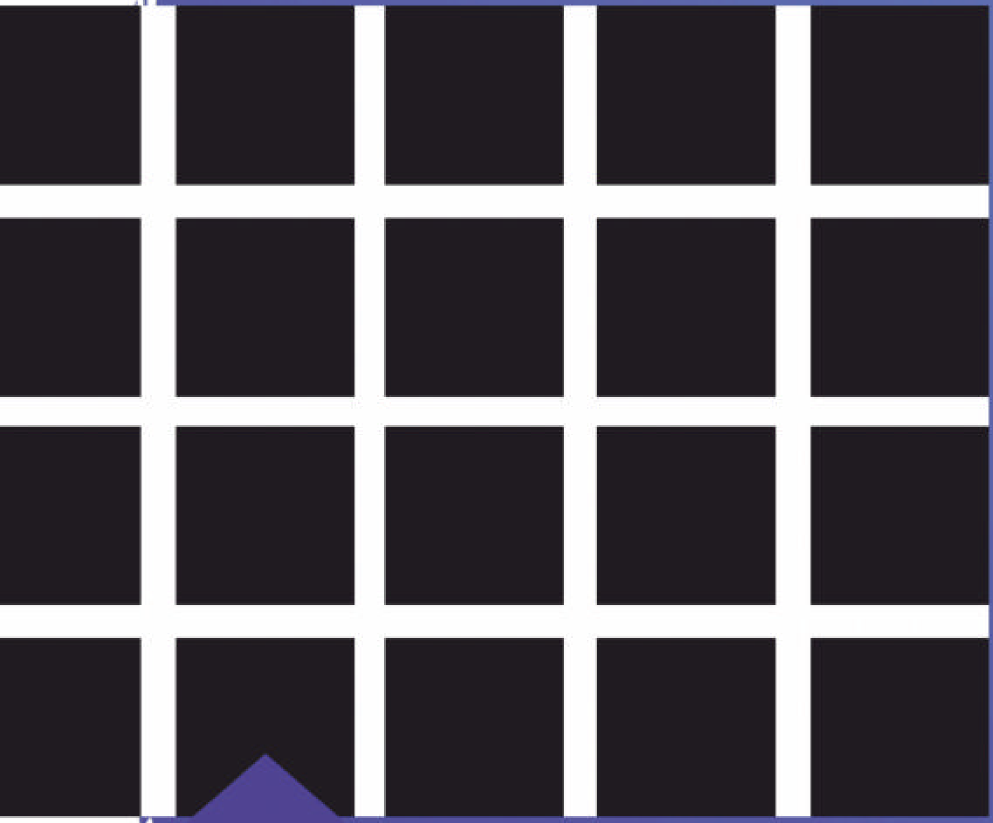
3 PROCESS SHAPE
Your memory stores shapes the brain has encountered. It compares these with the shapes analysed to find objects in the image.

4 PRODUCE PICTURE
Objects and shapes are pieced together to create your initial version of the double image.

5 QUICK RESULT
We are quick to make our first judgement of the illusion, as fast interpretation of visual information helps humans survive.

Physiological optical illusions

Images that perform physical transformations

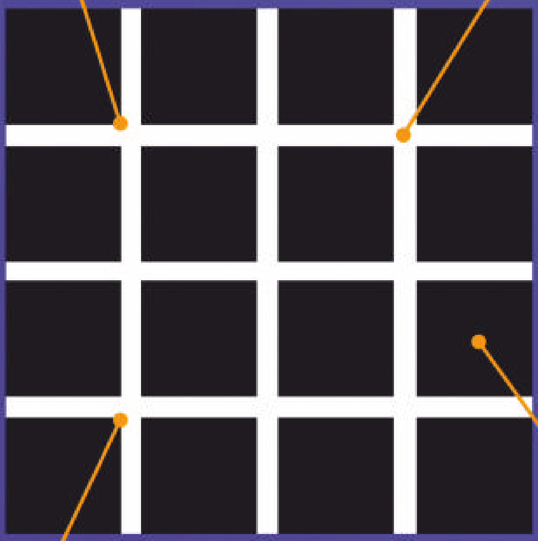


Disappearing dots

A Hermann grid is a famous optical illusion leaving the observer playing an impossible game of chase the dots. Scan your eyes over these black squares and take notice of the areas where the white lines cross. Can you see grey dots in your peripheral vision? Though they are scattered across the intersecting lines, as you focus on a single dot you will witness it disappearing. These dots were never really there, but made up by your eyes.

Contrast
The circles you see appearing and disappearing between the squares are due to the difference in lightness between the black and white areas. These dots are grey in colour, a combination of the contrasting tones.

Focus
When looking directly at one, the dot disappears. This is because the photoreceptors in the centre of your eye are sharp and clear. Darker squares are less able to inhibit the bright centre.



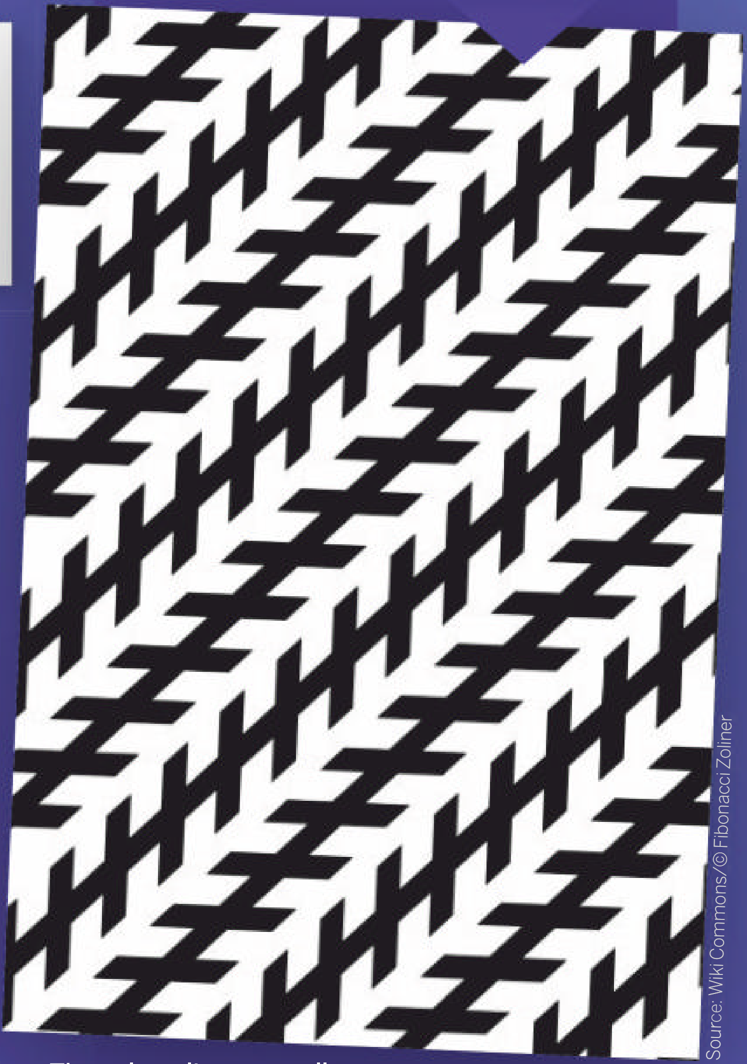
Peripheral issues
When parts of the image enter your peripheral vision, they become less accurate. The brain is filling in the gaps left by our eyes' limited field of view. It perceives the white intersections with protruding black corners as grey.

Solid block
No matter where your eyes rest on the grid, the black squares are always interpreted by your eyes as black since these areas have no surrounding exposure to light.

Leaning lines

Do you think that the long black lines in this image are parallel to one another? Do they all travel in the same direction or are they tilting different ways? This illusion is all down to the multiple short lines intersecting the long ones. While the long diagonal lines appear to tilt in different directions, they actually all cross the picture at exactly the same angle.

How can the addition of these smaller lines distort the picture so drastically? The science behind this illusion is all about how the brain processes an angle. One theory is that our brains tend to perceive small acute angles as being smaller than they really are, while we also overestimate the size of larger obtuse angles. In distorting the angle created between the long and short lines, the edges of the longer lines become warped in our heads. Each long line appears to tilt in the direction of the smaller angle. These angles are more likely to be misinterpreted when viewed on lines which are neither horizontal nor vertical, which is why they are positioned diagonally.



These long lines actually run parallel to each other

Source: Wiki Commons/© Fibonacci Zollner

THE PROCESS

1 OBSERVE IMAGE
When presented with the image, your eyes relay visual information to the brain. You see the colour, brightness and position of the image's components.

2 FIX TARGET
Some physiological illusions require you to fixate on one target for a long period, while in others this is simply the area you first happen to glance at.

3 RECEPTOR REACTION
Cells at the back of the eye absorb the light photons from the image. Light at the centre of vision, as well as the colour white and bright light, provide the highest stimulation.

4 CHANGING GAZE
As you move your eyes to target a new area, these illusions begin. Different photoreceptors are being stimulated as new light and shapes are exposed to the eyes.

5 ALTERED IMAGE
Physiological illusions create a change in brightness, movement, colour or tilt. As you take in new elements of the images, previously clear sections can become confused in position or tone.

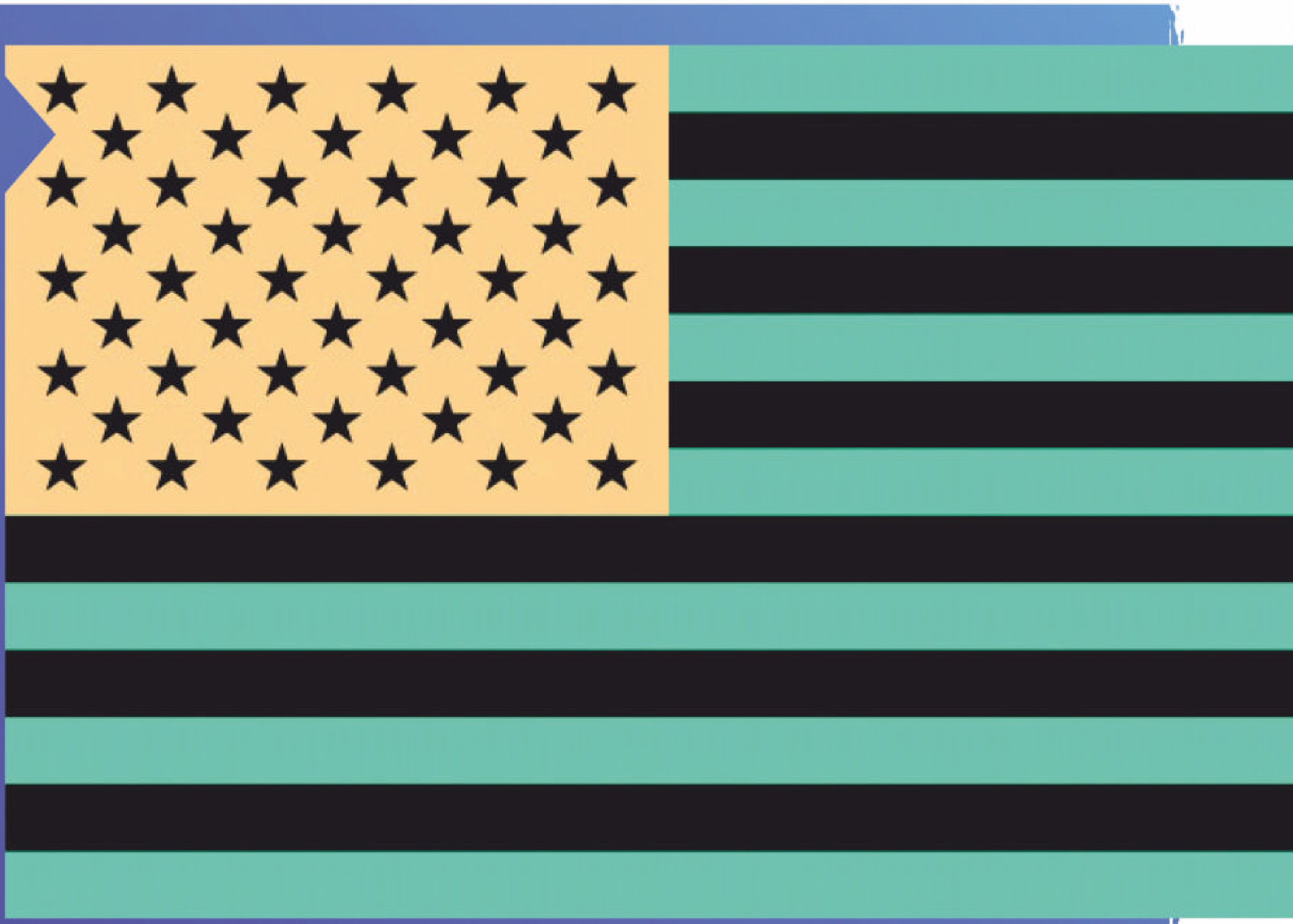
DID YOU KNOW? *Some of the earliest optical illusions were used on ancient Greek rooftops to make them appear curved*

Colour correction

This version of the American flag has the right patterns and shapes, but wildly wrong colours. Green, orange and black have been used in place of red, blue and white. These may seem like randomly selected colours, but what if you were able to see the true-coloured flag through this image?

To make sure you're able to find the image's hidden flag you will need to first scan the code with any smart device to view it on a bright screen. When you have your flag ready, begin by focusing on the bottom-right corner of the rectangle of stars. Stare at this section for at least 30 seconds without averting your gaze, then look away from the image and look at a plain surface such as the wall or a piece of paper. Can you see an after image? Blinking may help you find the flag.

AR ZONE!
SCAN HERE



1 Colour selection

Green and orange appear to have no link with the design of the flag. When observing a colour wheel, however, you'll see the tones have in fact been carefully selected. Facing green on the wheel lies red, while facing orange is blue. This makes them opposite colours.

2 Stare out

When you look at something, specific colour receptors in your eyes are stimulated based on the tones of the object in front of you. As you stare at the colours in this picture for an extended period of time, the receptors recognising green and orange become fatigued and less responsive to that colour of light.

3 Fresh vision

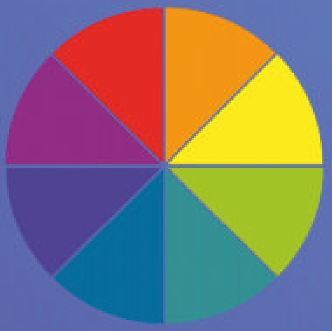
As your eyes look away, these visual receptors are able to rest, stimulating the unused receptors. The opposite colours are produced briefly as a result, which in this case are blue and red, showing the true flag.

4 Background selection

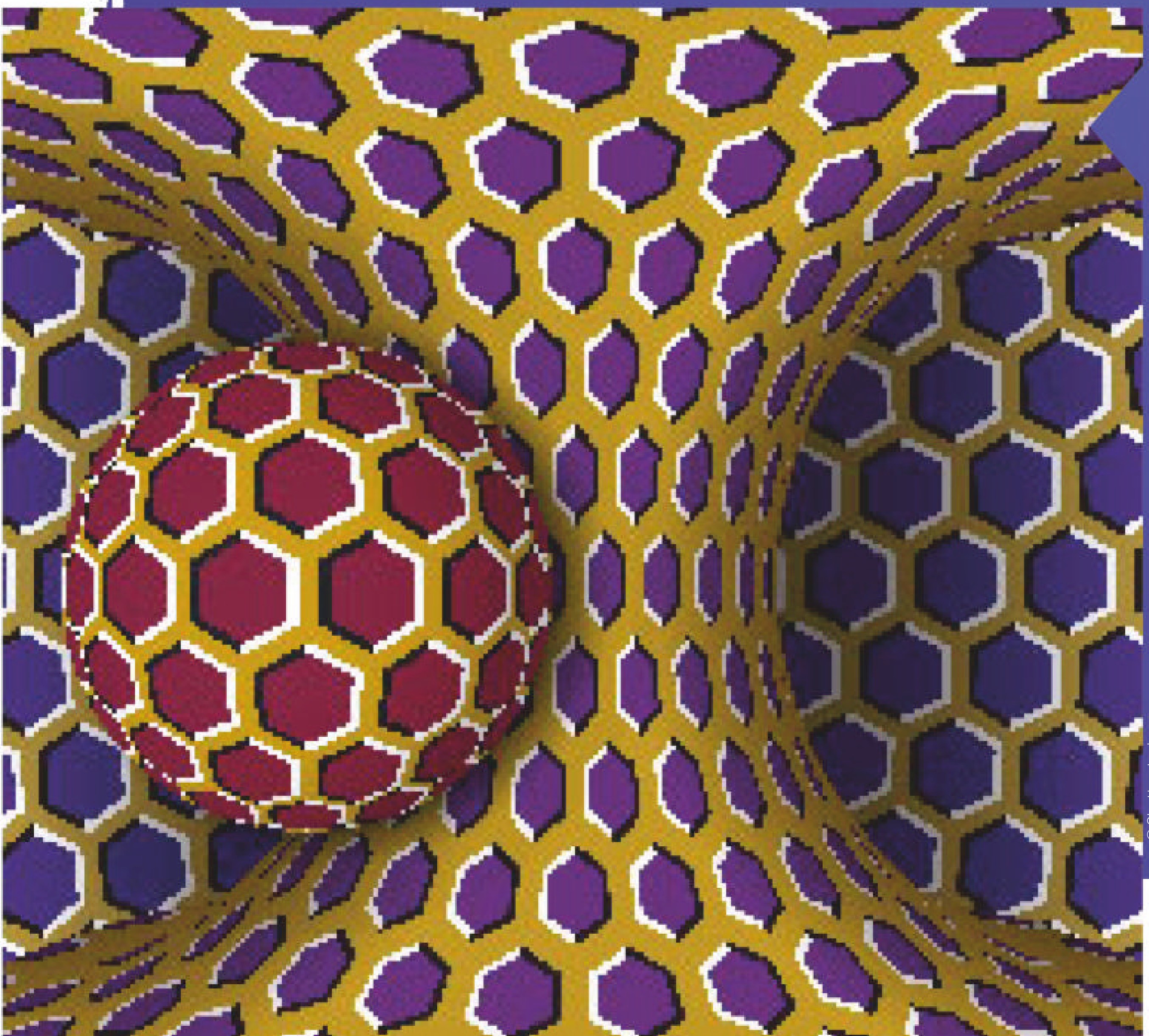
The plain background helps you to see the afterimage. The image remains in your eyes for a while due to the overstimulation that's caused by staring for so long at the bright inverted image.

5 Fade away

This afterimage illusion will remain for around 30 seconds before your eyes' photoreceptors readjust to normal stimulation.



Colours opposite each other on a colour wheel are complementary



© Shutterstock

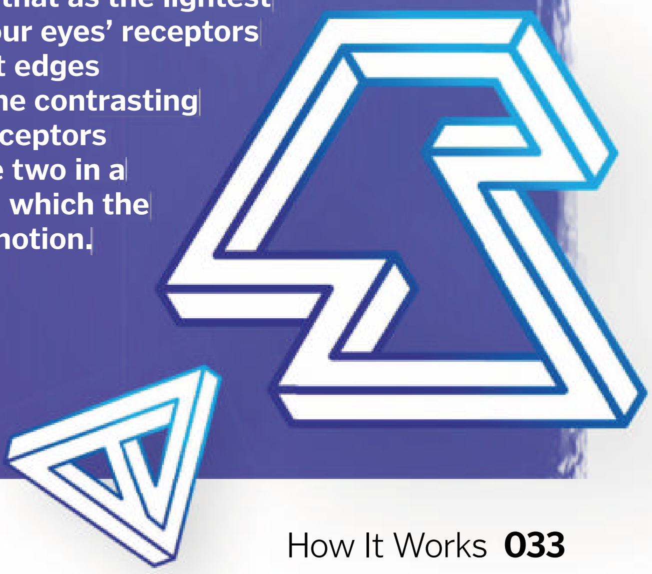
Dancing imagery

To most people looking at this image, the sphere filled with burgundy-coloured hexagons appears to continuously roll to the right around a purple-hexagon pillar. Created by Yurii Perepadia, a graphic designer and illustrator from Ukraine, the image is a perfect example of illusory motion.

One thing you will notice about this type of physiological optical illusion is that they normally have sections of white incorporated into the pattern. In this case the hexagons which seem to move to the right have white sections lining their right-hand side, while those appearing to move to the left have white lining their left.

Scientists believe that as the lightest shade, white turns our eyes' receptors 'on'. With these light edges positioned next to the contrasting dark edges, photoreceptors bounce between the two in a flickering sensation, which the brain interprets as motion.

The best way to slow down the motion is to intently stare at one hexagon



Cognitive optical illusions

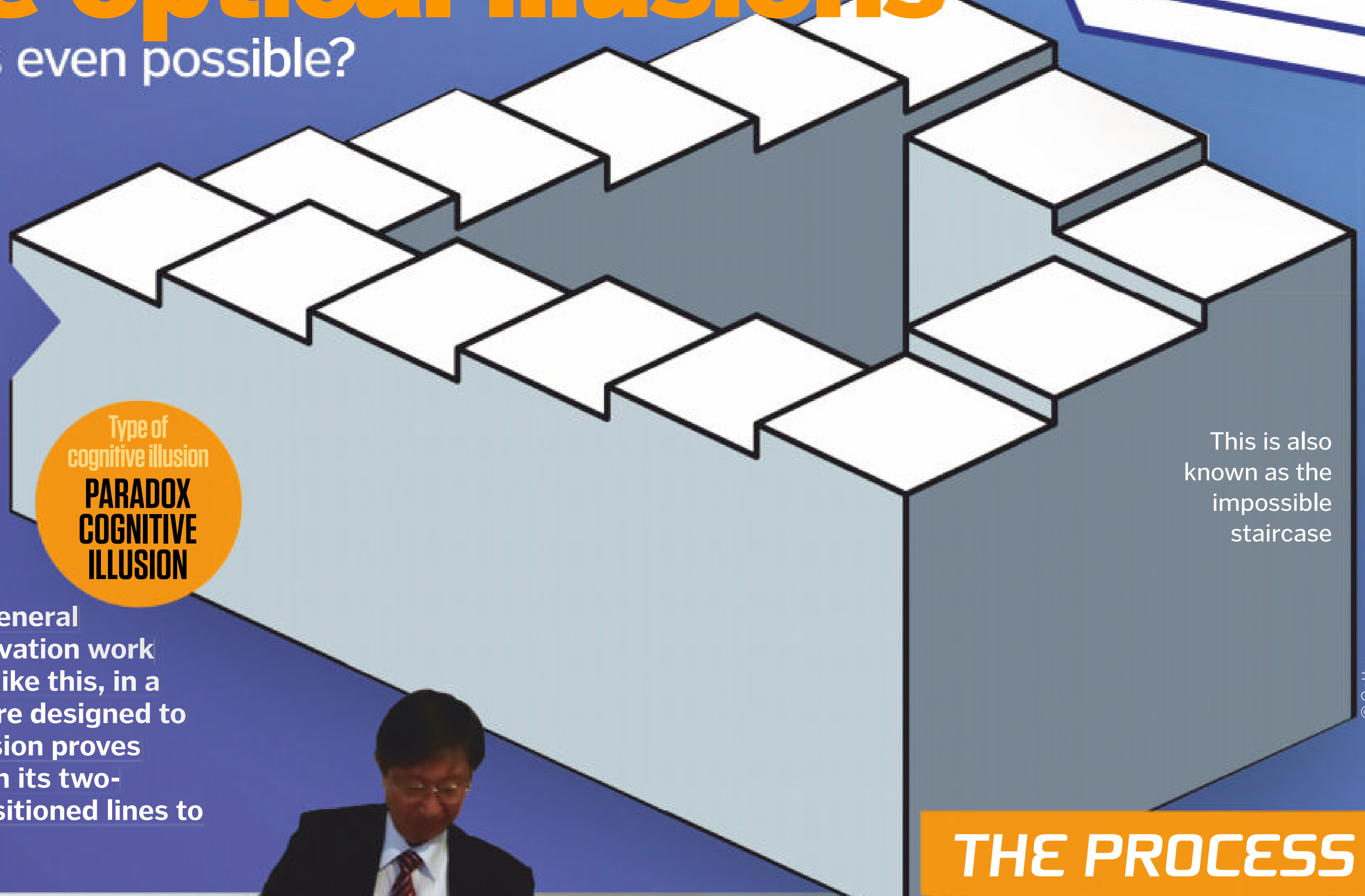
How are these sights even possible?

The never-ending climb

For those who find walking up stairs a chore, this image might be your worst nightmare. Where do these stairs stop? This illusion, known as the Penrose stairs, is designed to hold no start or end point. If you were to try and climb these stairs in real life you would be climbing forever and never reach a higher point.

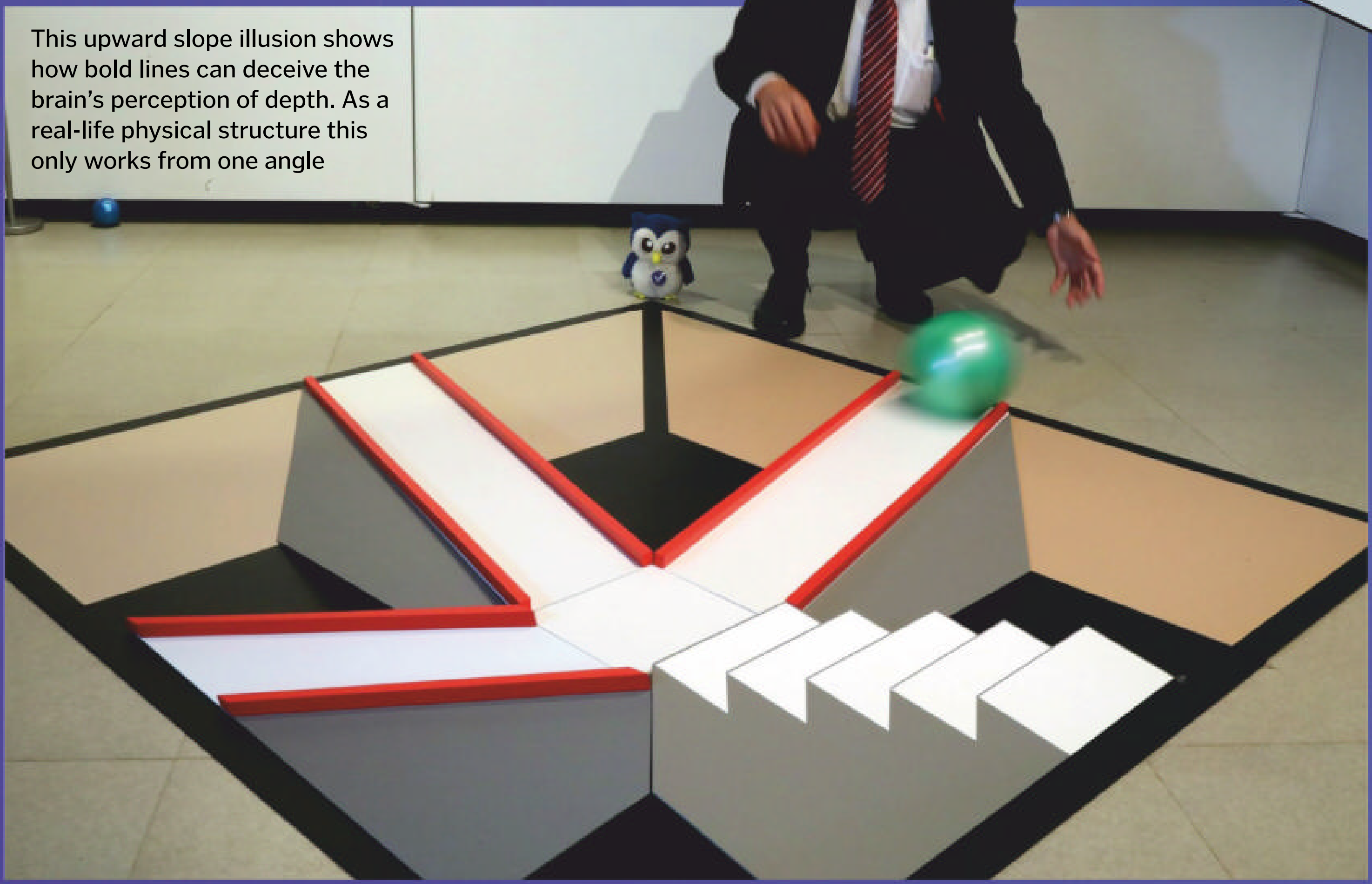
When taking in this image, your general knowledge of the way stairs and elevation work tells you that stairs cannot operate like this, in a continuous loop. Paradox illusions are designed to show the impossible. While this illusion proves possible on paper, it will only work in its two-dimensional form, with carefully positioned lines to trick the brain.

Type of cognitive illusion
PARADOX COGNITIVE ILLUSION



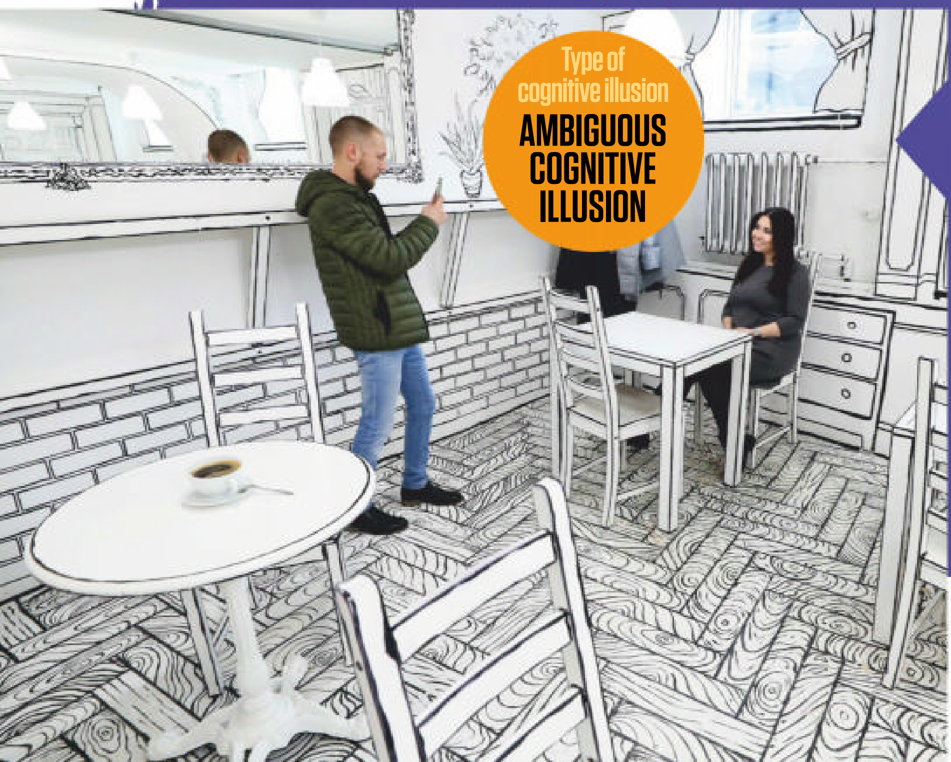
This is also known as the impossible staircase

© Getty



This upward slope illusion shows how bold lines can deceive the brain's perception of depth. As a real-life physical structure this only works from one angle

© Getty



Type of cognitive illusion
AMBIGUOUS COGNITIVE ILLUSION

© Getty

Cartoon café

Some illusions have the ability to change your perception of what you see and require your brain to switch between interpretations. This café in St Petersburg, Russia, challenges your brain's sense of depth. The black-and-white furniture makes the room look as if it were a 2D sketch. It is the presence of the customers that forces the brain to process the true 3D. Your eyes use shadows and lighting to help see dimensions, but this café is purposely brightly lit to remove these depth giveaways.

The BWCafe was designed by artist Anfisa Toshina

THE PROCESS

1 BUILT KNOWLEDGE

Through our experiences, our brains become familiar with the physical world.

2 OBSERVE IMAGE

When looking at a cognitive illusion, our eyes provide our brains with the visual information to piece together physical objects.

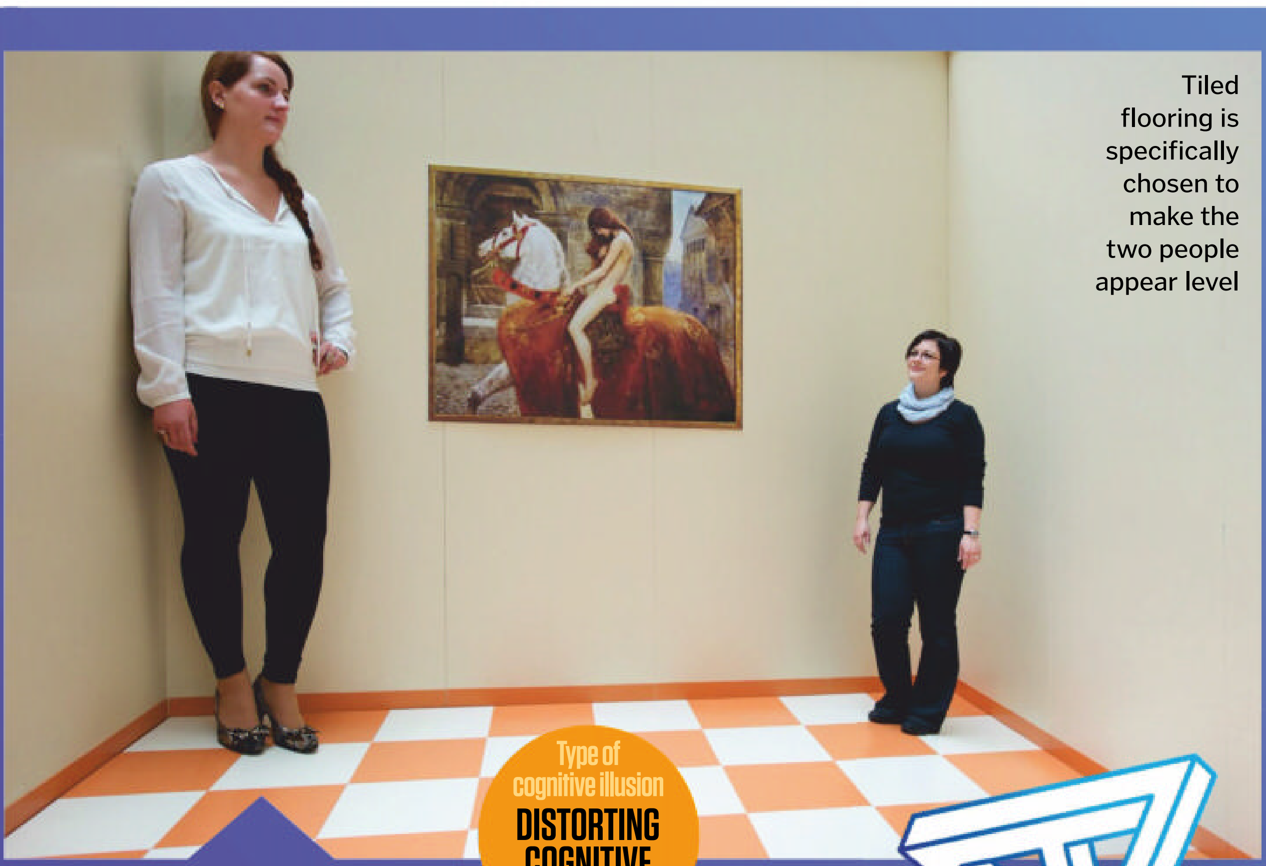
3 CONFLICTING FACTS

These illusions are designed to create a scenario that is physically impossible. As your brain processes it, you become amazed at seeing something happening that you know cannot.

4 ACCEPTANCE

There is nothing else the brain can do but accept this conflicting information and be mesmerised by the illusion.

DID YOU KNOW? *Ames rooms were used in the* Lord of the Rings *films to make Gandalf seem huge next to the hobbits*



Tiled flooring is specifically chosen to make the two people appear level

© Getty

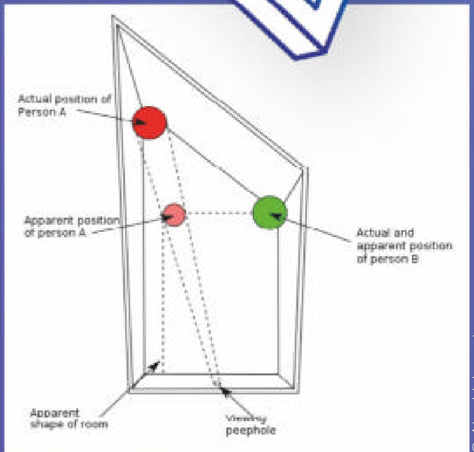
Type of cognitive illusion

DISTORTING COGNITIVE ILLUSION

Extreme size

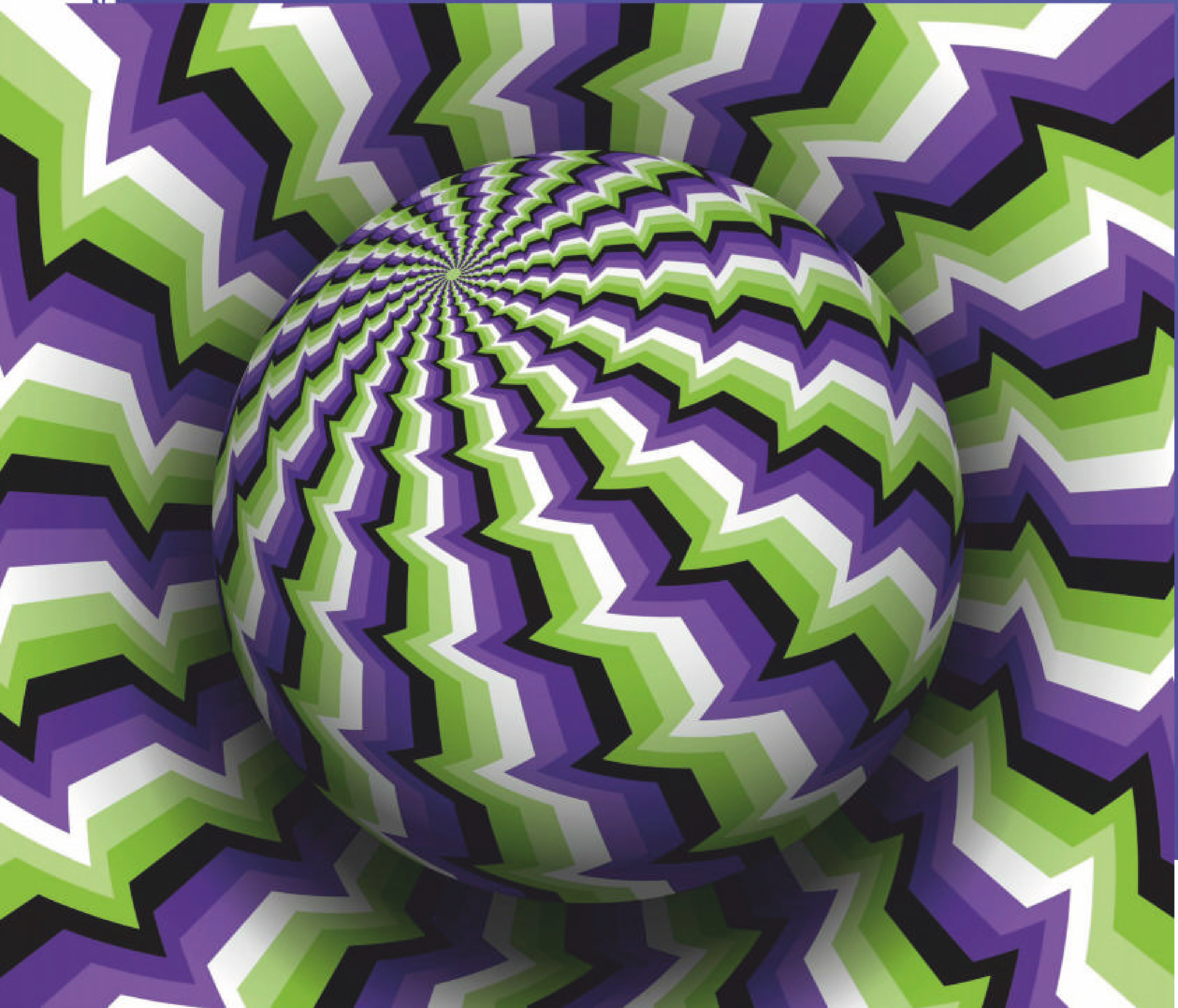
This is an Ames room, a room where you can appear to tower over your taller friends or shrink to the size of a baby. As an example of a distorting illusion, this room is all about hiding the true shapes and positions from your eyes and brain. When viewed from a specific angle, the room's true dimensions are hidden. Careful detail and artwork is added to make the room appear a regular square shape.

When two individuals stand in the far corners, they appear to be standing in line with each other, with one giant person looming over a miniature version of the other. But the floor is not level. The corner where the smaller person stands is at an incline, putting them lower down. Your eyes and brain, used to seeing rectangular rooms, don't notice the slanted walls.


Actual position of Person A
Apparent position of person A
Actual and apparent position of person B
Apparent shape of room
Viewing peephole

From the viewing area it doesn't look like the smaller person is further away from you

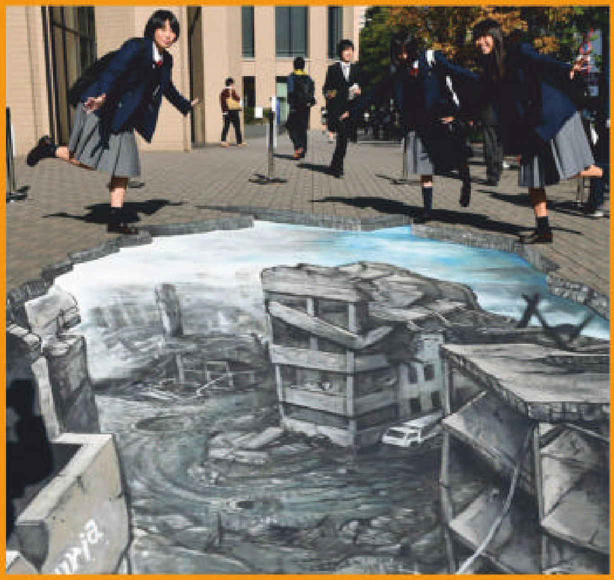
© Alex Valavanis



© Getty

3D street art

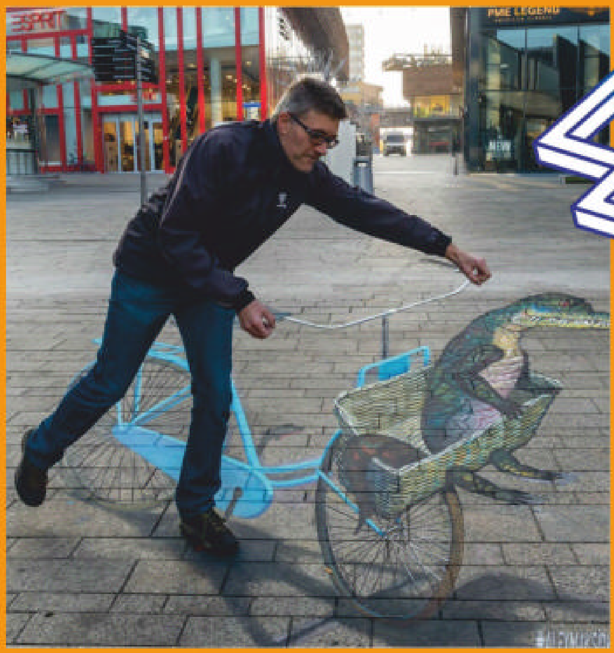
Art is often considered very impressive when the paint on the canvas looks like it could be a photograph. This skill in realistic art allows vivid images to be transferred onto a surface in whichever medium the artist excels in. When hanging up in a gallery this art has a photo-like quality, but when incorporated onto the streets the combination of realistic art and the real world's features have the potential to present optical illusions in the most unexpected locations. This adds interesting images to an otherwise regular street and allows people to engage with the art.



© Getty

Walking over a warzone

At Meiji University in Tokyo, Amnesty International used this optical illusion to bring the devastation of war in Syria onto the campus. Walking past this scene, which appeared to lie beneath the concrete floor, made students think about what was happening at an alternative location. By initially confusing the brain into seeing a hidden depth that wasn't really there, it reminded passers-by that although only an illusion to them, to those in Syria this devastation is reality.



© Getty

Cycling with a crocodile

Once a year in Almere, Netherlands, artists in the city are allowed to take to the streets and express their talent and quirks. This one, from 2015, uses the angle of lines on the floor to make you see a bike standing up by itself as you approach it. No person has been drawn riding the bike, giving those who are amazed by the illusion the opportunity to take to the saddle for a perfect photo.

Your nervous system

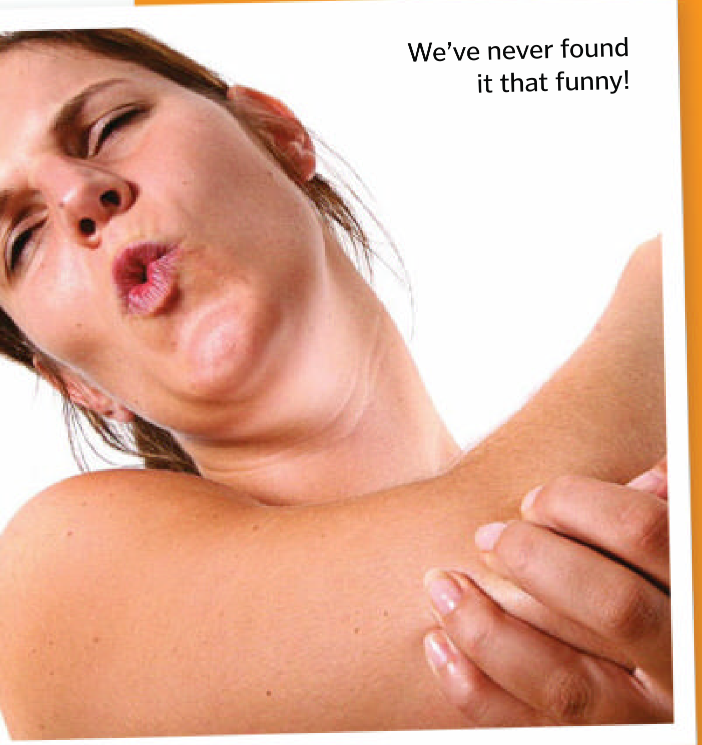
A breakdown of the specialised cells in your body which connect you with the outside world

Like any organisation, your success depends upon communication between your individual members. In a sense you actually are this communication, since it is the magic that makes you a single, clever creature. Your built-in communications network, known as the nervous system, perceives the outside world, keeps all body parts working in harmony and forms the thoughts and memories that make you unique.

The nervous system comprises hundreds of billions of specialised cells called neurons. A typical neuron consists of a compact cell body, protruding filaments called dendrites and a long single fibre called an axon. The axon can transmit signals to other neurons and to muscle cells, while the dendrite can receive signals from other neurons and sensory cells. A neuron's axon may extend across the brain or body and branch off hundreds of times.

When something excites a neuron, the cell body will send an electrical charge down the length of an axon, triggering axon terminals to release chemicals called neurotransmitters. These neurotransmitters can travel to receptors on dendrites of an adjoining neuron across a small gap called a synapse. Depending on the type of neurotransmitter and receptor, the signal will either excite the adjoining neuron to fire an electrical charge down its own axon, or the signal may inhibit the neuron from firing. The complex connections and signal patterns among the hundreds of billions of neurons in your brain form thoughts, memories and other mental activities.

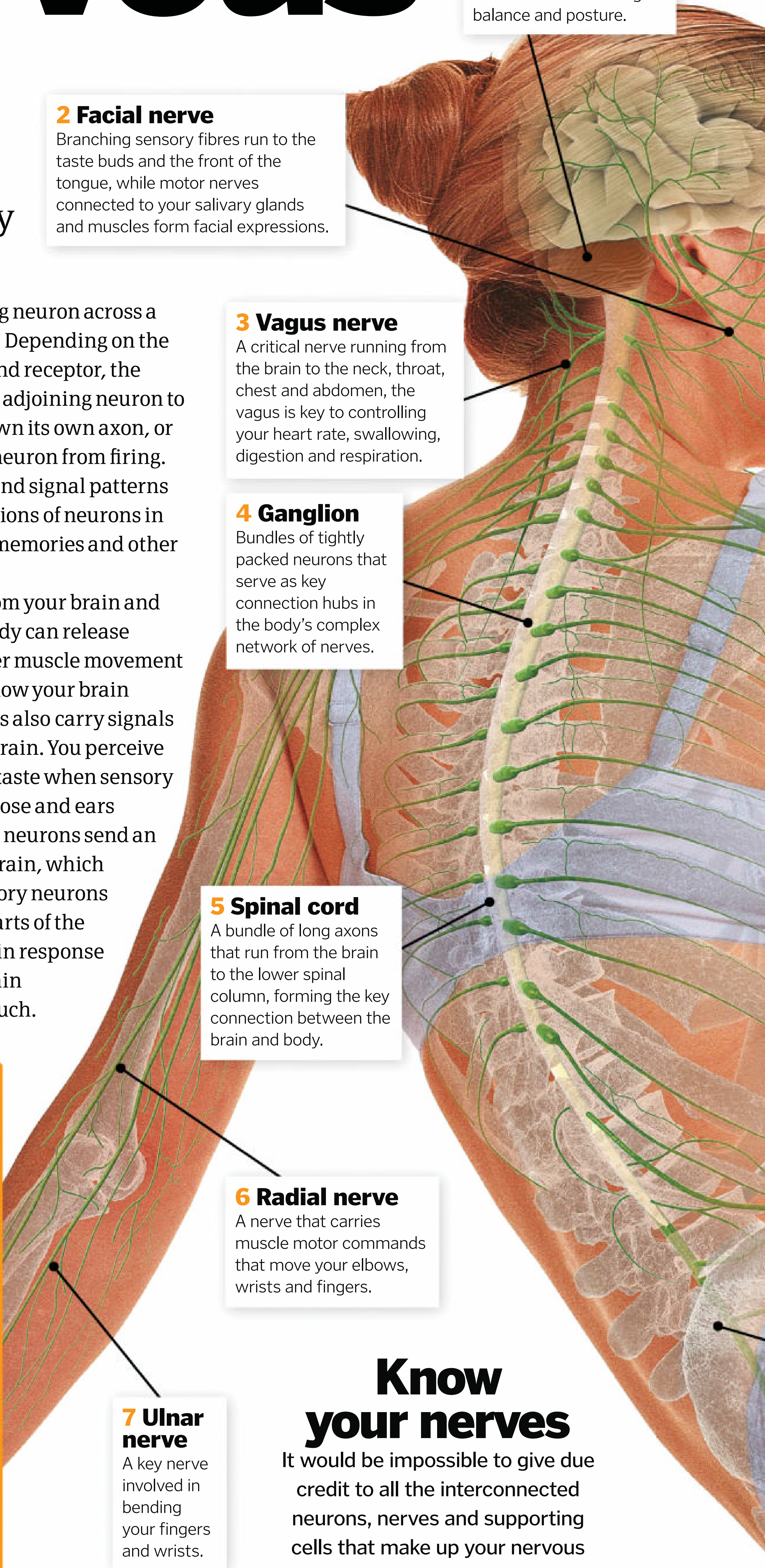
Axons that extend out from your brain and spinal column into your body can release neurotransmitters to trigger muscle movement and organ activity. This is how your brain controls your body. Neurons also carry signals from the body back to the brain. You perceive sights, sounds, smells and taste when sensory cells in your eyes, mouth, nose and ears excite nearby neurons. The neurons send an electrical signal up to the brain, which then interprets them. Sensory neurons near your skin and other parts of the body fire an electric signal in response to pressure, which your brain perceives as the sense of touch.



We've never found it funny!

Hitting a nerve: not-so-funny bone

Most of the larger nerves in your body are insulated by muscle, bone and tissue. The big exception is the ulnar nerve, which runs down your arm by way of your elbow. The nerve carries motor commands to your ring and pinkie fingers and relays sensory information back to the central nervous system. If you bang your elbow, the humerus bone bumps the nerve, jarring the axons inside, which your brain interprets as a tingling sensation.



Know your nerves

It would be impossible to give due credit to all the interconnected neurons, nerves and supporting cells that make up your nervous system, but we can point out some of the most valuable players

1 Cerebellum
Latin for 'little brain', the cerebellum coordinates and fine-tunes skilled movements based on incoming sensory information. It's also involved in maintaining balance and posture.

2 Facial nerve
Branching sensory fibres run to the taste buds and the front of the tongue, while motor nerves connected to your salivary glands and muscles form facial expressions.

3 Vagus nerve
A critical nerve running from the brain to the neck, throat, chest and abdomen, the vagus is key to controlling your heart rate, swallowing, digestion and respiration.

4 Ganglion
Bundles of tightly packed neurons that serve as key connection hubs in the body's complex network of nerves.

5 Spinal cord
A bundle of long axons that run from the brain to the lower spinal column, forming the key connection between the brain and body.

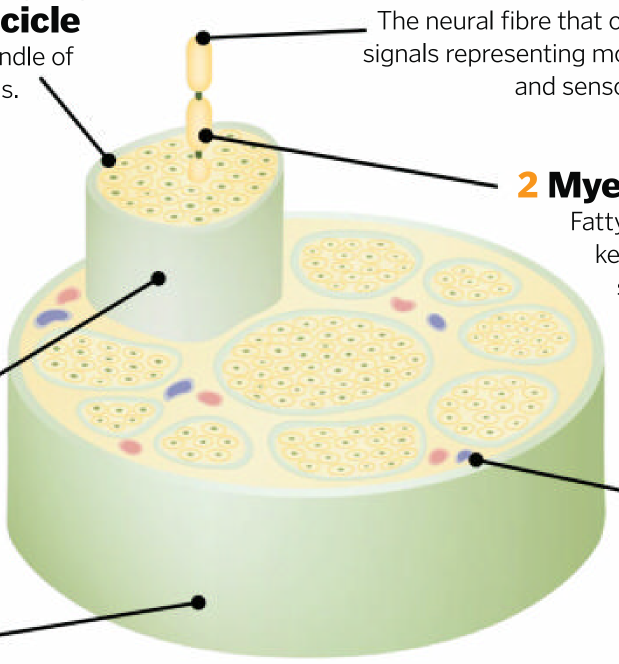
6 Radial nerve
A nerve that carries muscle motor commands that move your elbows, wrists and fingers.

7 Ulnar nerve
A key nerve involved in bending your fingers and wrists.

DID YOU KNOW? *Elephants have 257 billion neurons – three times more than the average human brain*

Anatomy of a nerve

Nerves are sturdy enough to protect your sensitive axons from damage, but flexible enough to snake around your body parts



1 Axon
The neural fibre that carries electrical signals representing motor commands and sensory information.

2 Myelin sheath
Fatty insulation that keeps axons from short-circuiting.

3 Perineurium
Sheath of connective tissue that protects each fascicle.

4 Nerve fascicle
A bundle of axons.

5 Blood vessels
Supply of blood that provides neurons with energy.

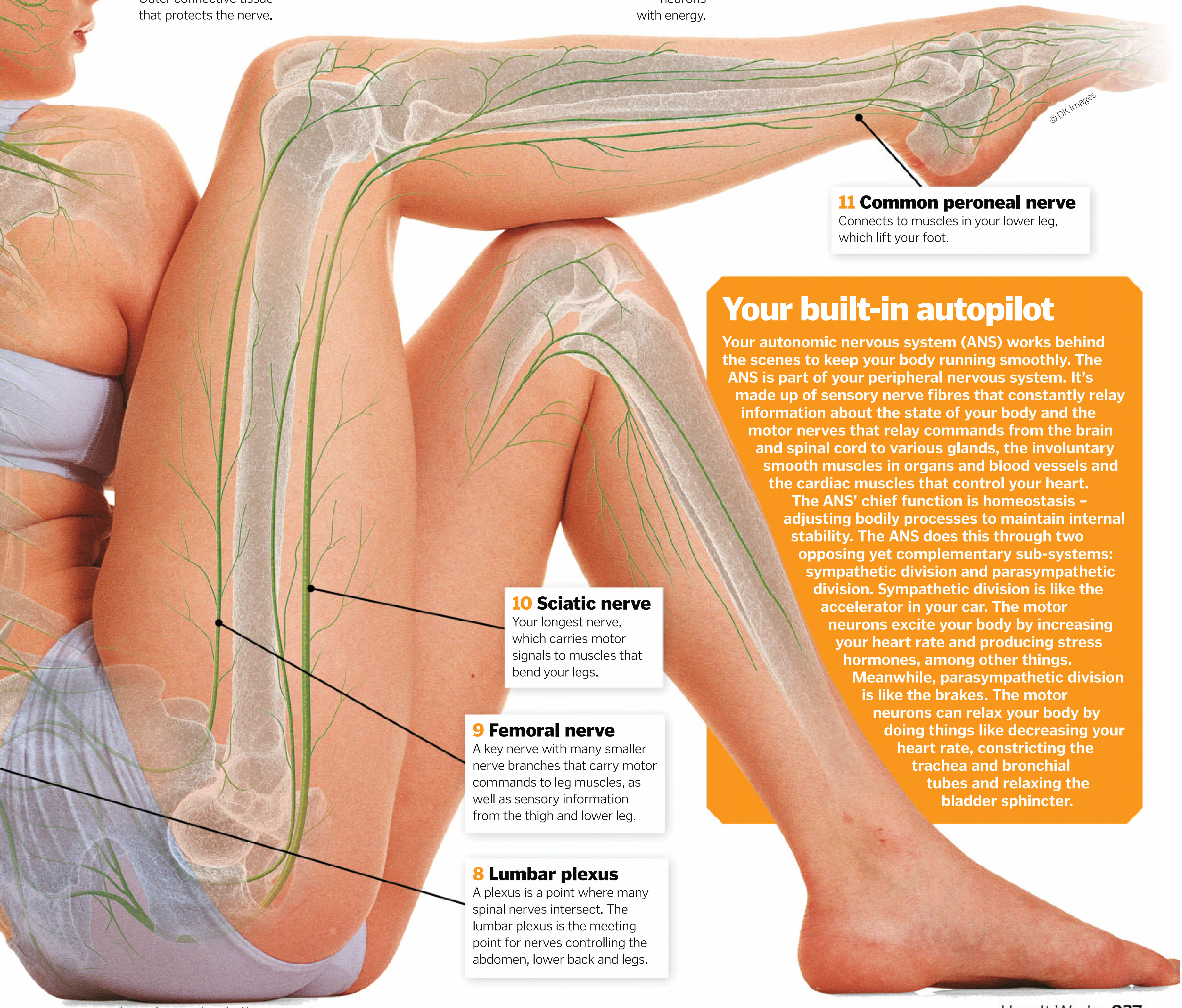
6 Epineurium
Outer connective tissue that protects the nerve.

What nerve!

Your neurons are fragile cells, and for the most part can't be replaced if they get damaged. So instead of bare axons running through our bodies, we have nerves.

A nerve is like an electrical cable housing thousands – or millions – of axons in a protective sheath of tissue. Nerves extend out from your brain and spinal column, known as the central nervous system, to the rest of your body. There are 12 pairs of nerves extending from the brain and 31 pairs extending from the spinal cord. The nerves branch off in your body, forming a network called the peripheral nervous system.

The afferent division of the peripheral nervous system relays signals from sensory neurons back to the central nervous system, while the efferent division relays instructions from the central nervous system to muscles and glands. Most nerves carry both types of signals.



© DK Images

8 Lumbar plexus
A plexus is a point where many spinal nerves intersect. The lumbar plexus is the meeting point for nerves controlling the abdomen, lower back and legs.

9 Femoral nerve
A key nerve with many smaller nerve branches that carry motor commands to leg muscles, as well as sensory information from the thigh and lower leg.

10 Sciatic nerve
Your longest nerve, which carries motor signals to muscles that bend your legs.

11 Common peroneal nerve
Connects to muscles in your lower leg, which lift your foot.

Your built-in autopilot

Your autonomic nervous system (ANS) works behind the scenes to keep your body running smoothly. The ANS is part of your peripheral nervous system. It's made up of sensory nerve fibres that constantly relay information about the state of your body and the motor nerves that relay commands from the brain and spinal cord to various glands, the involuntary smooth muscles in organs and blood vessels and the cardiac muscles that control your heart. The ANS' chief function is homeostasis – adjusting bodily processes to maintain internal stability. The ANS does this through two opposing yet complementary sub-systems: sympathetic division and parasympathetic division. Sympathetic division is like the accelerator in your car. The motor neurons excite your body by increasing your heart rate and producing stress hormones, among other things. Meanwhile, parasympathetic division is like the brakes. The motor neurons can relax your body by doing things like decreasing your heart rate, constricting the trachea and bronchial tubes and relaxing the bladder sphincter.

Light and colour

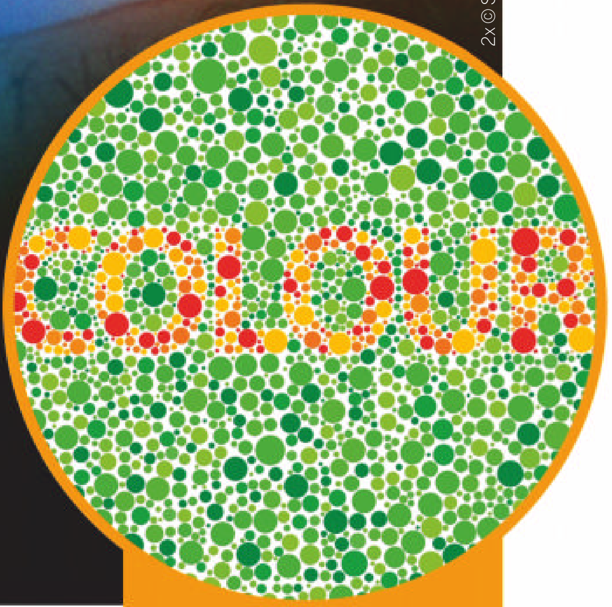
Why do we see things in colour, not black and white?

Light such as sunlight contains the full electromagnetic spectrum, but our eyes are only sensitive to a wavelength of approximately 390 to 700 nanometres (nm), known as visible light. As sunlight shines on an object, such as a green apple, the object absorbs some of the incident light – the direct light that hits the surface. However, it reflects a specific wavelength of light, in this case corresponding to the colour green, which is received by sensors in the eyes known as rods and cones. These tell the brain that the colour of the object is green.

White paper appears white because it reflects all visible light. We see black when all visible light is absorbed by an object. Certain pigments within an object will absorb light and define which wavelengths they will emit. The primary colours of red, blue and green combine to create the many different colours that we see.

Our eyes combine red, blue and green to allow us to see a variety of colours

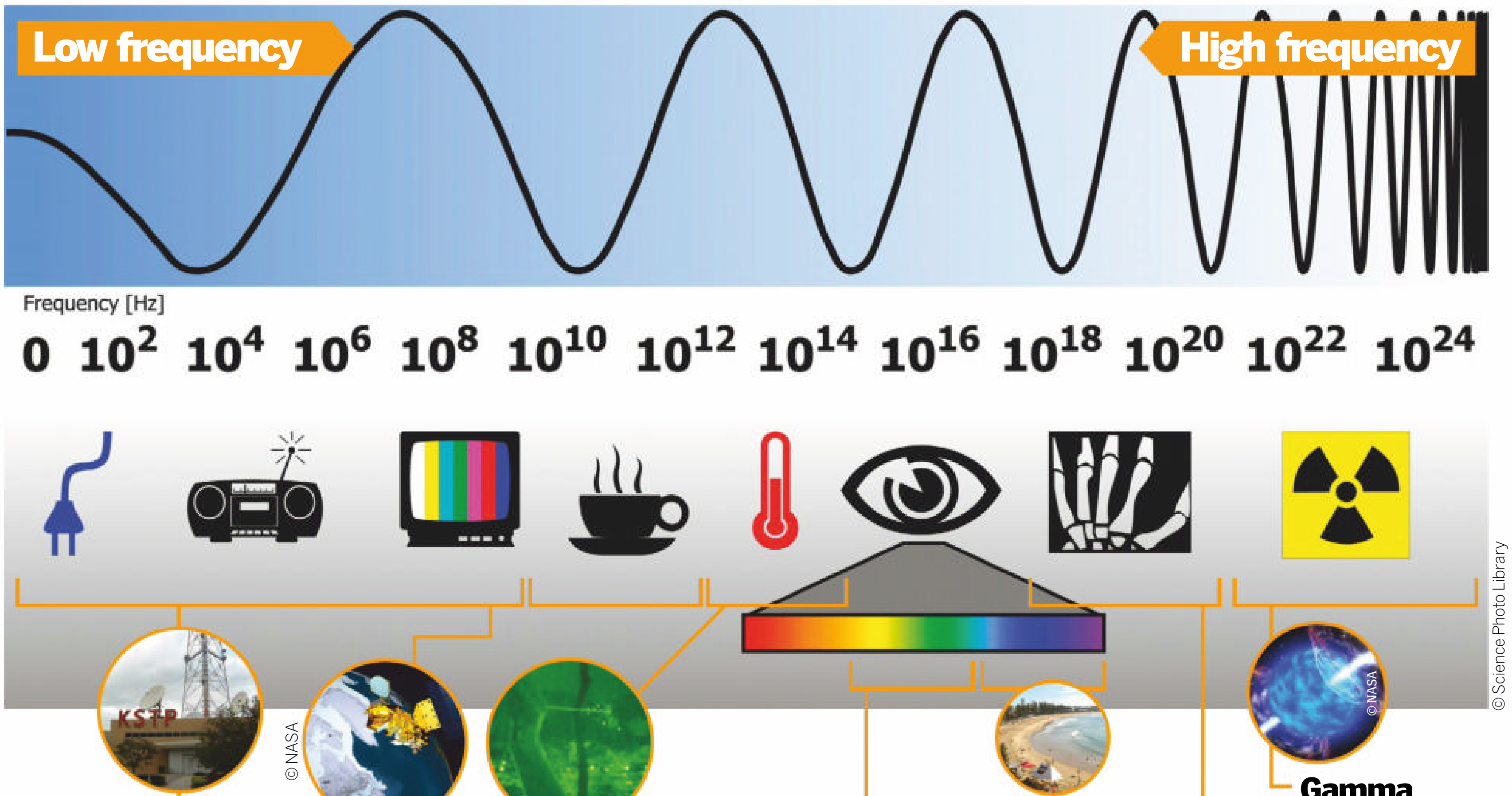
2x © Science Photo Library



Someone with colour blindness will have difficulty seeing the word above

The electromagnetic spectrum

Visible light makes up only a small portion of the spectrum. Have a look at where other electromagnetic waves feature



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Radio
10cm to 100km plus
Very useful waves with a whole range of applications, like broadcasting radio and television.

Microwave
1mm to 10cm
Microwaves are used for cooking food and satellite communications.

Infrared
700nm to 1mm
Almost everything emits infrared waves, allowing night-vision cameras to see perfectly in the dark.

Visible light
390 to 700nm
The only way you'll read a copy of **How It Works** is by your eye receiving visible light.

Ultraviolet
10 to 390nm
They might give you a nice tan, but these rays from the Sun can also damage your skin.

X-rays
0.01 to 10nm
A useful wave in medicine, since they can penetrate clothing and skin but not bone.

Gamma rays
<0.01nm
Nuclear explosions and gamma-ray bursts in space both emit these invisible waves.

Colour blindness

The rods and cones in your eyes are unique, and therefore we all perceive colours slightly differently. However, some people cannot discern between one colour and another. Three types of cones – red, green and blue – create the colours we see, while the rods record brightness. People with colour blindness have fewer of certain types of cones and more of another. This means they are more receptive to certain colours than others, and will even be unable to distinguish between some colours. The most common colour confusion is between red and green.

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WORLD'S LONGEST MEGA PIPELINES HOW PENGUINS SWIM FALCON 9 ROCKET
INTENSIVE CARE
HOW TO THINK YOURSELF SMART
HOW TO GROW A HUMAN HEART
BODY OF A RUNNER

EXPLORE THE
THE MILKY WAY

It's just one of two trillion galaxies in the observable universe, but it's our home. Join us as we journey across the Milky Way

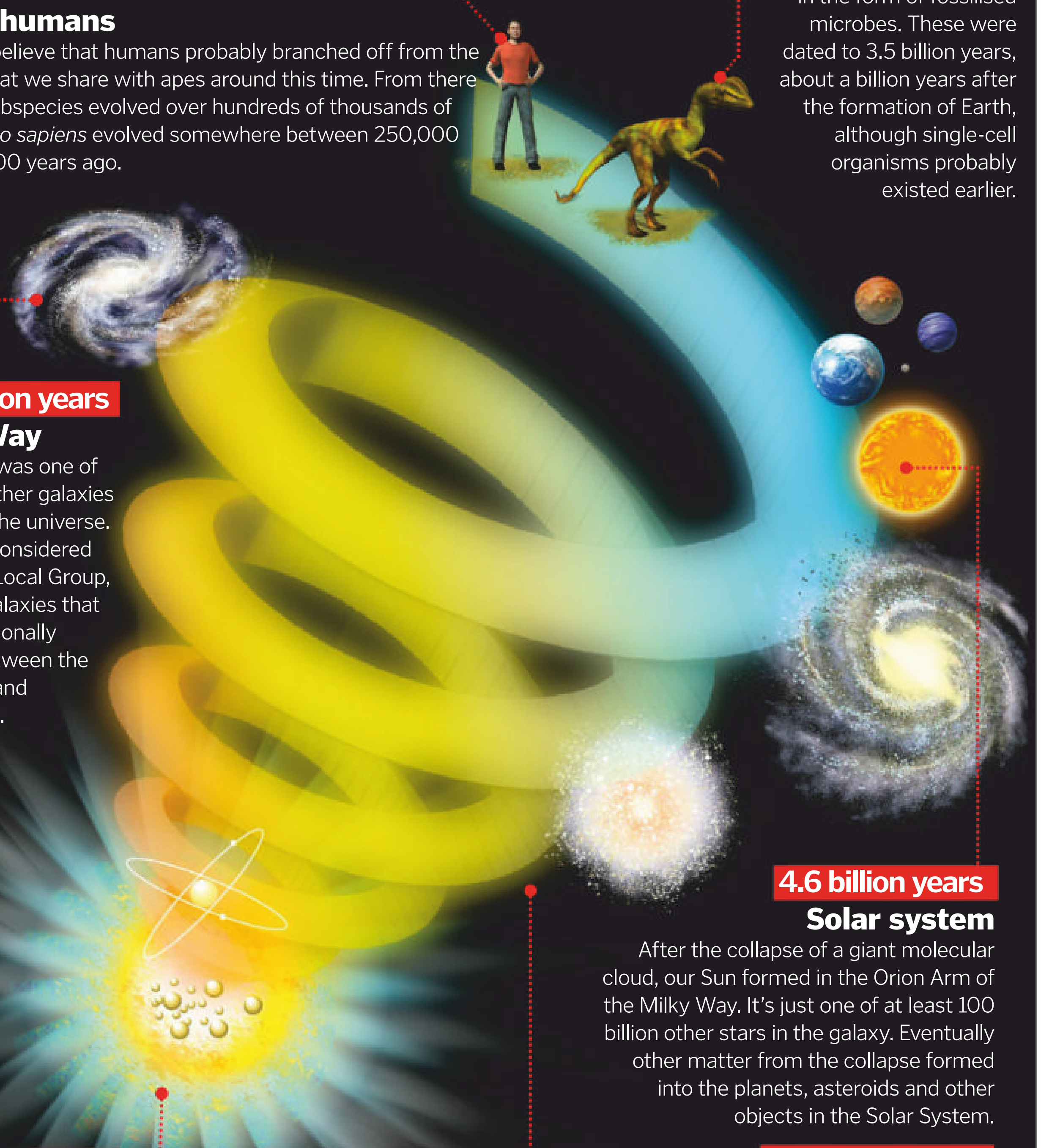
DID YOU KNOW? *According to Greek mythology, the Milky Way was formed when Hera spilt milk while breastfeeding*

The Milky Way is our galaxy, home to our Solar System. It formed more than 13 billion years ago, less than a billion years after the Big Bang. The galaxy is estimated to be about 100,000 light years in diameter and 1,000 light years thick. It is part of a system of about 50 galaxies known as the Local Group, which is part of the Virgo Supercluster. Containing as many as 100 billion planets and 400 billion stars, the Milky Way is a spiral galaxy. It has a centre, known as a 'bulge', which is surrounded by a flat disc comprising several loose arms that contain stars and their orbiting bodies as well as gases and dust. The centre is thought to contain a massive black hole and a complex radio source known as 'Sagittarius A*'. Around the outside of the Milky Way there is a halo containing dark matter and a very small percentage of the galaxy's total number of stars. Astronomers have observed that the Milky Way is actually a special type of spiral galaxy called a barred spiral, meaning that it has a bar-shaped distribution of stars running across its centre.

Aristotle first wrote of the Milky Way in the mid-300s BCE. He broke from other Greek philosophers who believed that the milky streak in the sky might be stars. Aristotle thought that it was a sort of fiery emission coming from a cluster of very large stars, and that it resided in the Earth's atmosphere. Ancient astronomers continued to speculate about the true nature of the Milky Way until Galileo determined in 1610 that it comprised a massive number of stars.

In 1755 Immanuel Kant realised that the Milky Way rotated and was held together by gravity. 30 years later William Herschel attempted to depict the shape of the Milky Way and the Sun's location in it by counting and recording the position of visible stars. Finally, Edwin Hubble determined in the 1920s that there were nebulae beyond the Milky Way, proving that there were other galaxies in the universe. Hubble is also

Timeline of the universe



3.5 billion years

First life

The first examples of life on Earth have been found in the form of fossilised microbes. These were dated to 3.5 billion years, about a billion years after the formation of Earth, although single-cell organisms probably existed earlier.

5 to 7 million years

Rise of humans

Scientists believe that humans probably branched off from the ancestor that we share with apes around this time. From there different subspecies evolved over hundreds of thousands of years. *Homo sapiens* evolved somewhere between 250,000 and 400,000 years ago.

13.2 billion years

Milky Way

Our galaxy was one of billions of other galaxies forming in the universe. Today it is considered part of the Local Group, about 50 galaxies that are gravitationally situated between the Milky Way and Andromeda.

4.6 billion years

Solar system

After the collapse of a giant molecular cloud, our Sun formed in the Orion Arm of the Milky Way. It's just one of at least 100 billion other stars in the galaxy. Eventually other matter from the collapse formed into the planets, asteroids and other objects in the Solar System.

13.8 billion years

The Big Bang

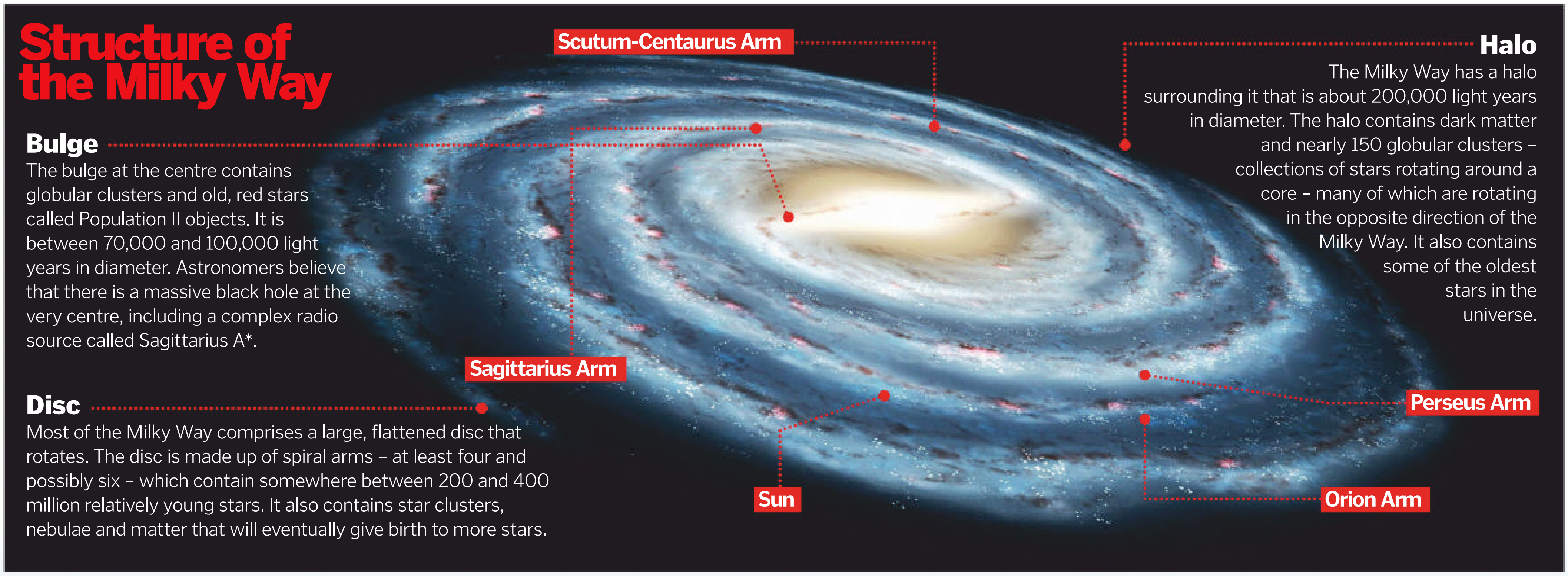
The prevailing theory about the origin of our universe begins with the Big Bang – an explosion in our once-infinite universe that resulted in previously contained matter and energy expanding outward and filling space.

13.5 billion years

Galaxy clusters

Gravity from the Big Bang made hydrogen and helium clouds shrink into webs that were millions of light years across, with large open spaces between each one. Galaxies formed within these clusters of clouds.

Structure of the Milky Way



Bulge

The bulge at the centre contains globular clusters and old, red stars called Population II objects. It is between 70,000 and 100,000 light years in diameter. Astronomers believe that there is a massive black hole at the very centre, including a complex radio source called Sagittarius A*.

Disc

Most of the Milky Way comprises a large, flattened disc that rotates. The disc is made up of spiral arms – at least four and possibly six – which contain somewhere between 200 and 400 million relatively young stars. It also contains star clusters, nebulae and matter that will eventually give birth to more stars.

Halo

The Milky Way has a halo surrounding it that is about 200,000 light years in diameter. The halo contains dark matter and nearly 150 globular clusters – collections of stars rotating around a core – many of which are rotating in the opposite direction of the Milky Way. It also contains some of the oldest stars in the universe.

© NASA

responsible for coming up with the classification system for galaxies that we use today, which includes spiral, elliptical and irregular galaxies.

For all our observations, the Milky Way is still mysterious. Determining its actual size and our location in it has been difficult since we can only observe from within; Herschel and astronomers before him believed that our Solar System was in its centre because of the apparently equal distribution of stars in our sky, for example.

Several different indirect methods have been used to calculate the actual size of the Milky Way. This includes using the period-luminosity relation of certain stars. The luminosity, or brightness of some stars pulse in a predictable pattern, which can be measured along with their apparent magnitude to estimate distance. In the early 20th century an astronomer named Harlow Shapley used some of these measurements to extrapolate the distances of globular clusters outside the Milky Way.

This showed that the Sun was not at the centre of the galaxy and provided a rough, although inaccurate estimate of the Milky Way's diameter. Today we can map the galaxy using telescopes that pick up light and radio waves emitted by gases and molecules floating in space.

The Milky Way isn't a static object – the arms rotate about the centre, and it is also moving in the direction of a large gravitational anomaly known as the Great Attractor. Our galaxy also has its own orbiting galaxies. The two largest of these satellite galaxies, the Small Magellanic Cloud and the Large Magellanic Cloud, create a vibrational warp in the Milky Way's disc as they orbit due to the presence of dark matter.

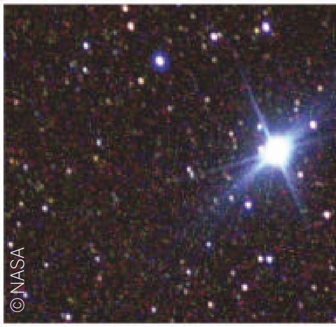
Because of light and other types of atmospheric pollution, it's difficult to view the Milky Way from Earth with the naked eye; it's best viewed in very rural areas under clear skies, and looks like a faint milky band of clouds stretching across the night sky. Light pollution maps are available online, and local astronomy clubs can help locate the best place to go to see it.

A digital composite of the Milky Way's disc over Tenerife

© Juan Carlos Casado

Trip through the Milky Way

A trip from Earth out beyond the edge of the Milky Way would mean travelling a distance of thousands of light years



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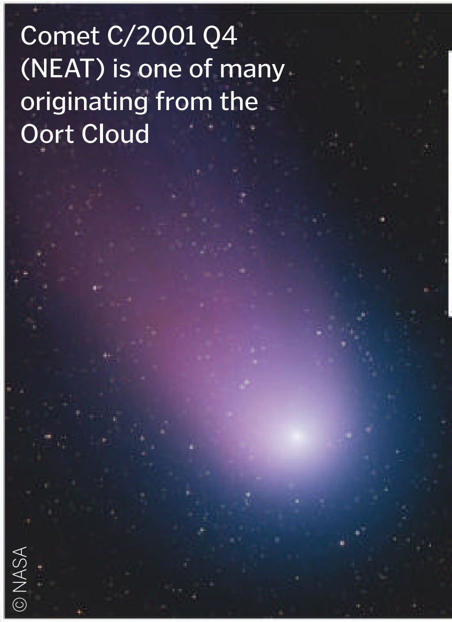

Comet C/2001 Q4 (NEAT) is one of many originating from the Oort Cloud

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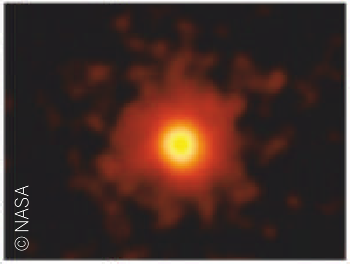

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4.24 light years

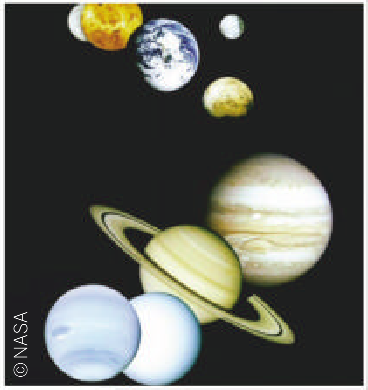
Nearest stars

Aside from the Sun, the nearest star to Earth is the red dwarf Proxima Centauri. Part of the three-star Alpha Centauri system, it's slightly closer to Earth than the more visible Alpha Centauri A and B. Sirius, the brightest star in the night sky, is 8.6 light years away.

6 billion kilometres

Oort Cloud and Kuiper Belt

The Oort Cloud is a cloud of comets believed to be the source of many of the comets in our Solar System. The Kuiper Belt is an area of the Solar System containing dwarf planets and other small astral bodies.



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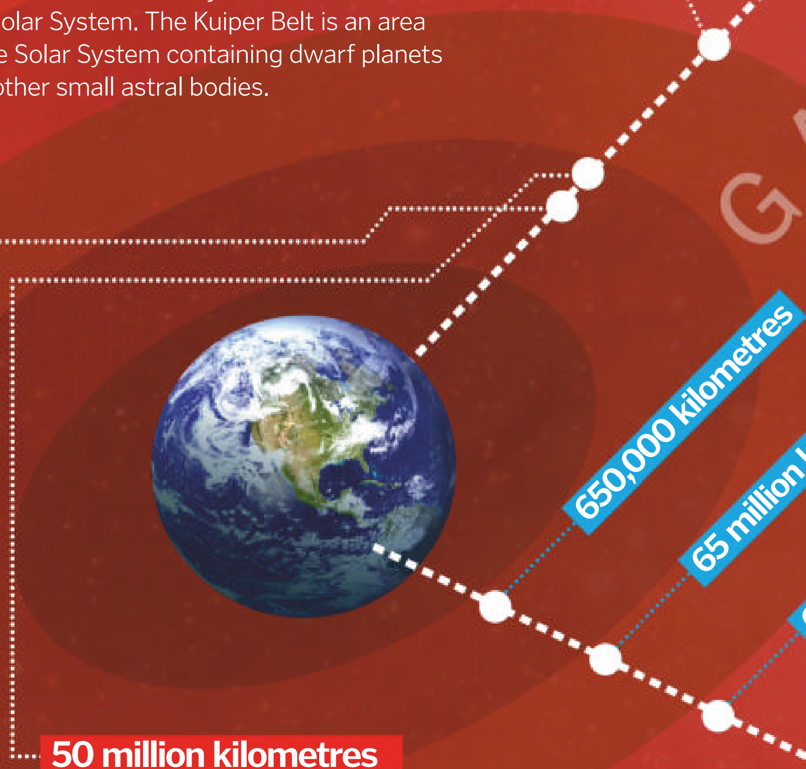
40 million kilometres

Solar System

We'll have to travel a while before coming upon the other planets that share our Solar System. At nearly 40 million kilometres away at the closest point in its orbit, Venus is our nearest neighbour. Once we reach the furthest planet from Earth, Neptune, we're about 4.4 billion kilometres away.



50 million kilometres

Near-Earth asteroids

There are more than 20,000 of these small rocky, metallic objects floating within 50 million kilometres of our home planet. Compared to the lifetime of other objects in the galaxy, these asteroids have life spans of just a few million years.

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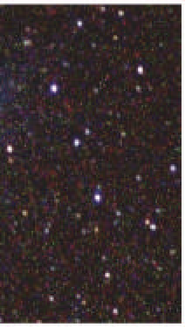
DID YOU KNOW? *The name 'Milky Way' comes from Latin and Greek astronomers who observed the stars' milky appearance*



300 light years

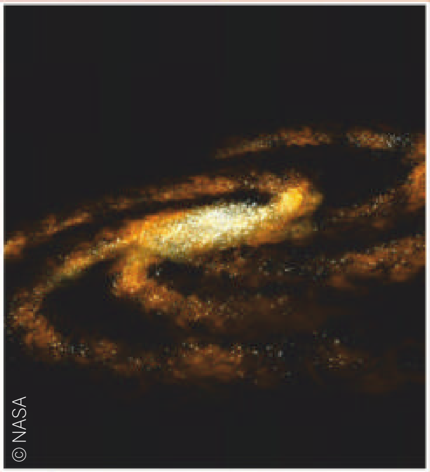
Neighbour stars

Once we get 100 light years away from Earth, we're nearing the outer edges of the Milky Way. Some of the better known stars past this distance include Canopus at more than 300 light years away and Betelgeuse at about 640 light years away.

1,000 light years

Milky Way

The edge of the Milky Way is about 1,000 light years away from Earth. Keep in mind that our Solar System is already on the outer edges of the Milky Way itself, about 28,000 light years from its centre.



© NASA

25,000 light years

Nearby galaxies

Now we're beyond the Milky Way, visiting other galaxies. There's a dwarf galaxy known as Canis Major being consumed by the Milky Way right now, 25,000 light years away. The closest galaxy outside of the Milky Way is the Sagittarius Dwarf Spheroidal Galaxy, 70,000 light years from Earth.

© NASA

300 million light years

Galaxy groups and galaxy clusters

The further we get, the greater the leaps in distance. Now we encounter groups of galaxies and other massive structures. The Great Wall, or Coma Wall, is a superstructure filling large spatial voids in the universe. It contains superclusters of galaxies and is more than 500 million light years long and 300 million light years wide.

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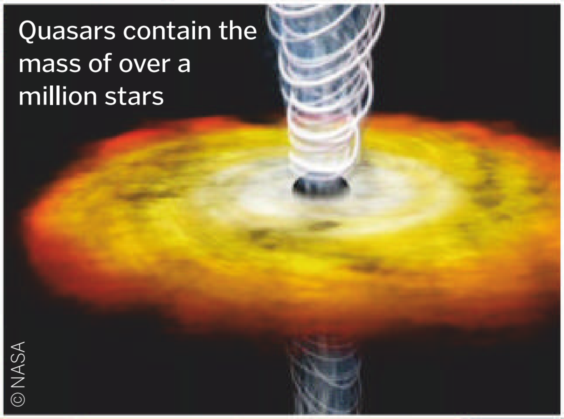


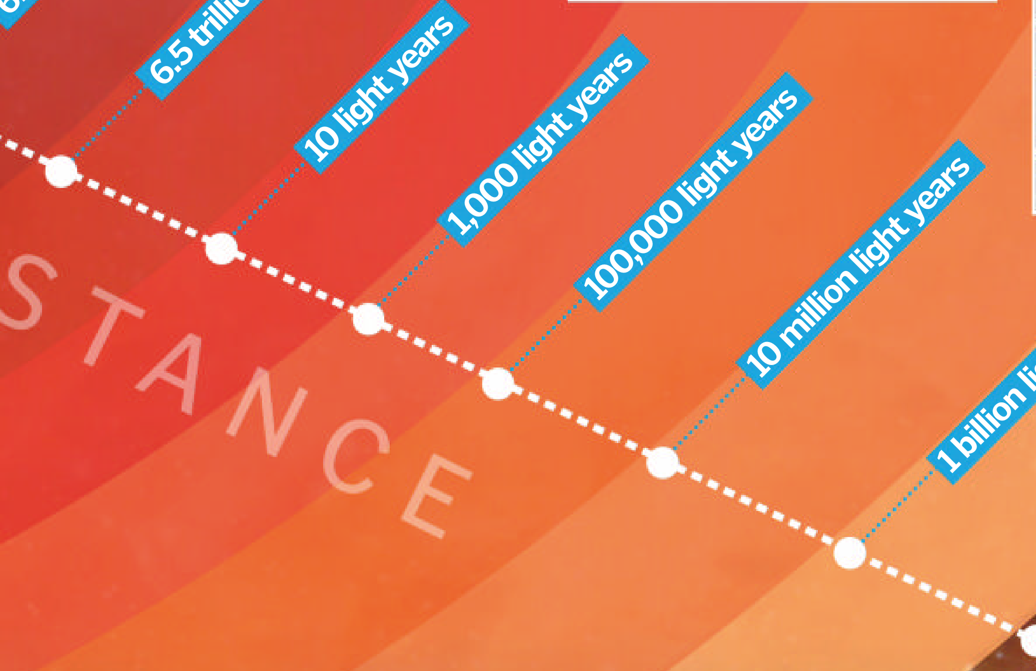
Quasars contain the mass of over a million stars

© NASA

580 million light years

Distant quasars and galaxies

Quasars are the most distant visible objects in the universe. The closest one is about 580 million light years away and the furthest is about 13 billion light years away. That means that on Earth we see the distant quasar, named ULAS J1342+0928, less than 690 million years after the Big Bang.



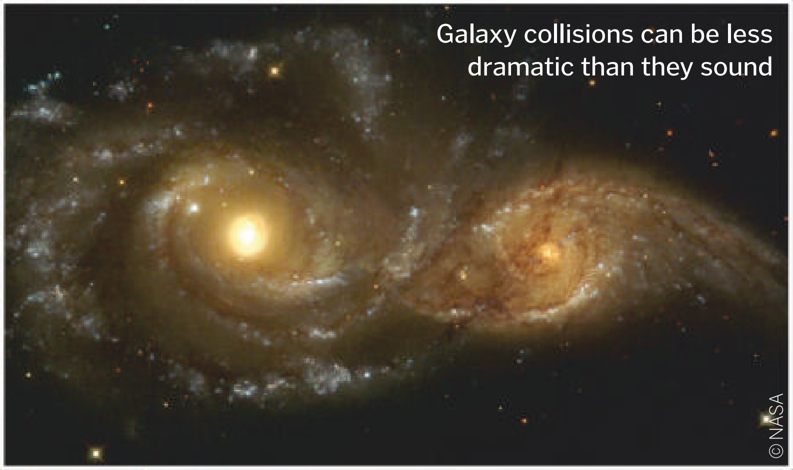
Galaxy on the move

The Sun travels around the galactic centre at 800,000 kilometres per hour, taking 225 million years to make one orbit. Our galaxy rotates differentially, which means that objects closer to its core orbit the core faster than the stars in the arms of the galaxy. The closer objects are to the centre, the less time they take to complete an orbit. The Milky Way rotates at about 210 kilometres per second. Our Solar System, located around 30,000 light years from the galactic core, completes an orbit once every 225 million years. The Milky Way is also moving through space at about 630 kilometres per second relative to the cosmic microwave background – the Big Bang's remnants. It moves in the direction of a gravitational anomaly in the universe, the Great Attractor.

When galaxies collide

Astronomers predict that in about 4.5 billion years the Andromeda Galaxy may collide with the Milky Way. The violent crash will result in a blob-like elliptical galaxy, dubbed 'Milkomeda'.

Currently Andromeda is about 2.5 million light years from the Milky Way, but it is moving towards our galaxy at 120 kilometres per second. The possibility of stars and planets within the galaxies actually colliding is highly unlikely, but the different gravitational fields will jostle them out of their current locations. Our Solar System could even be ejected during the collision, but that probably wouldn't affect the planets themselves much.



Galaxy collisions can be less dramatic than they sound

© NASA

SpaceX Dragon capsule

The first-ever commercial spacecraft to leave and return to Earth explained

When the NASA Space Shuttle was retired in 2011, several different companies competed to become NASA's new choice for cargo and crew transportation to the International Space Station (ISS) – and possibly beyond.

In 2006 and 2008 NASA awarded the private company SpaceX two contracts totalling roughly $2 billion (£1.59 billion), paving the way for the Dragon capsule to complete its first successful orbit and re-entry in December 2010.

Powered by a combination of solar panels and an advanced lithium battery, the Dragon capsule is large, allowing for the transportation of up to seven crew members or up to six tonnes of cargo. It uses 18 liquid-fuel thrusters equipped with dinitrogen tetroxide and monomethylhydrazine to manoeuvre while in orbit. Like NASA's Orion, the conical shape of the Dragon capsule is deemed the best for Earth re-entry, while also allowing for a sizeable interior.

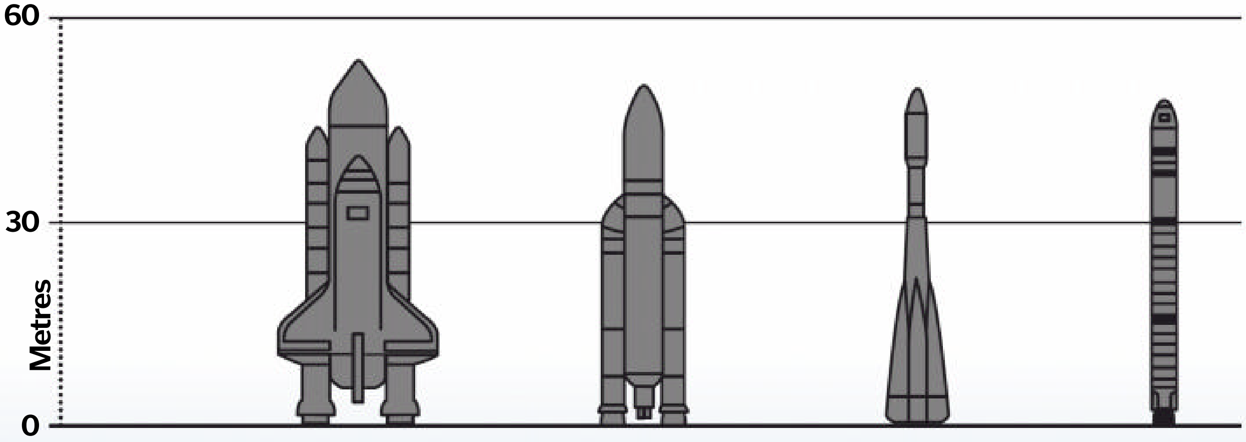
One of its defining features is a variant of NASA's Phenolic-Impregnated Carbon Ablator (PICA) heat shield. SpaceX's PICA-X heat shield advances on NASA's design in a number of places, notably its significantly reduced cost and added reusability. This allows it to be used hundreds of times, whereas NASA's currently does not survive its flight. This shield protects the capsule as it re-enters Earth's atmosphere at several thousand degrees and keeps the interior close to room temperature.

Three oversized parachutes slow its descent to Earth, although it can operate on only one if the other two should fail. The capsule has to land in water. The last flight of Dragon's first iteration touched down in the Atlantic Ocean off the coast of Florida after ferrying supplies to the ISS on 7 March 2020. Resupply missions – as well as missions delivering crew – will now be taken over by Dragon 2.

Dragon is able to dock with the ISS

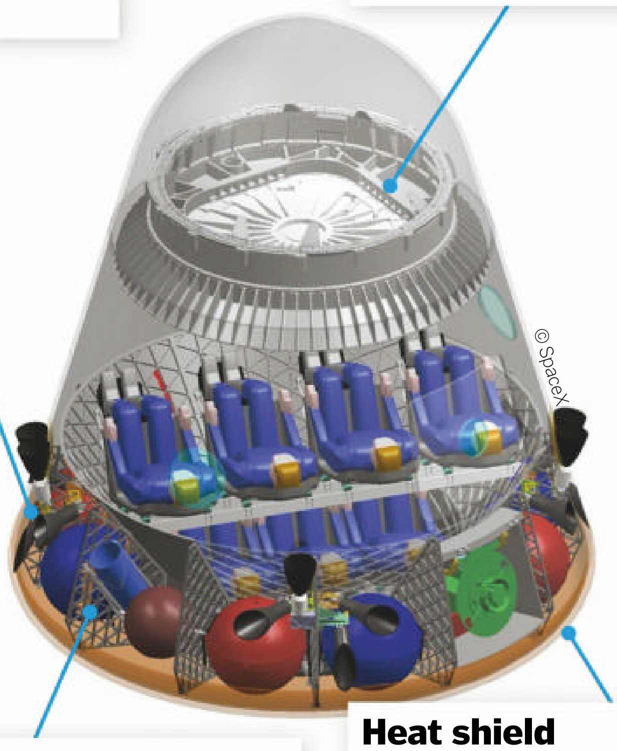
© SpaceX

Launch vehicles



	Space Shuttle	Ariane 5	Soyuz	Falcon 9
Origin:	US	Europe	Russia	US
Cargo to ISS:	16.1 tonnes	16 tonnes	8.2 tonnes	22.8 tonnes

Inside the Dragon capsule



© SpaceX

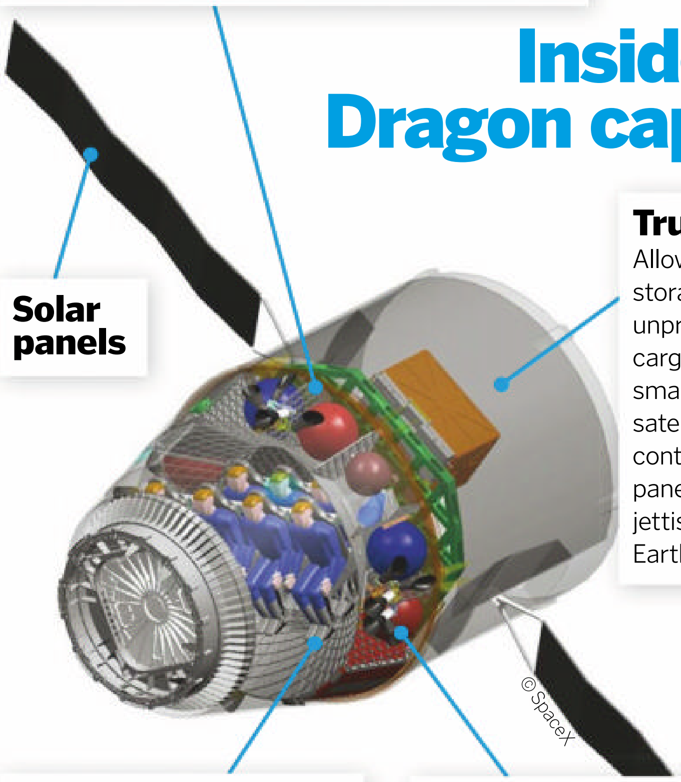
Launch abort
Unlike NASA's Orion spacecraft, which uses a rocket to 'pull' the capsule off in an emergency, the Dragon uses its lower boosters to 'push' the capsule off the launch pad if required.

Nose cone
This protects the spacecraft during launch and before the separation stage, and also contains the mechanism for docking with the ISS.

Parachutes
Three parachutes, each 35 metres in diameter, deploy at 3,000 metres and slow the spacecraft's descent to about five metres per second.

Heat shield
Advancements in technology allow the PICA-X heat shield to be reusable. This provides protection from the heat when entering Earth's atmosphere.

Service cabin
This section contains the thrusters, fuel and parachutes, remaining attached to the spacecraft for the duration of the mission.



© SpaceX

Solar panels

Trunk
Allows for the storage of unpressurised cargo such as small deployable satellites. Also contains the solar panels, and is jettisoned before Earth re-entry.

Pressurised cabin
Equipped with hatches and windows, this section provides protection against radiation and micrometeorites for crew and cargo.

Draco thrusters
These provide precise control of the spacecraft, enabling safe docking with the ISS and a return to Earth within a few hundred metres of a target.

DID YOU KNOW? *An upgraded Dragon capsule has now taken human passengers safely to the ISS*

The statistics

© SpaceX

SpaceX Dragon capsule

Height: 4.4 metres
Diameter: 3.66 metres
Launch mass: 6,000 kilograms
Re-entry mass: 3,000 kilograms
Top speed: 27,000 kilometres per hour
Flight time:
One week to two years

© NASA

Falcon 9

SpaceX's Falcon 9 rocket is responsible for taking the Dragon capsule into orbit. Developed from the ground up by SpaceX for cost-efficient transport into orbit, the Falcon 9 is a two-stage launch vehicle that uses liquid oxygen and rocket-grade kerosene. Its aluminium-lithium alloy exterior uses the strongest and most reliable welding techniques available.

The Falcon 9 first-stage is powered by nine Merlin engines, which are the highest performing American hydrocarbon rockets ever flown. The engines generates over 1 million pounds of thrust in a vacuum, employing the same technology as that used in the Apollo Moon missions.

In line with the company's goal of reusability, SpaceX has managed to make the first stage reusable, with it able to return to a drone ship after launching a payload. The second stage, which separates from the Dragon capsule and falls to Earth at a much higher altitude, will require significant advances in heat-shield technology to withstand atmospheric temperatures and become reusable.

Elon Musk, founder and CEO of SpaceX, with the impressive Falcon 9
© SpaceX

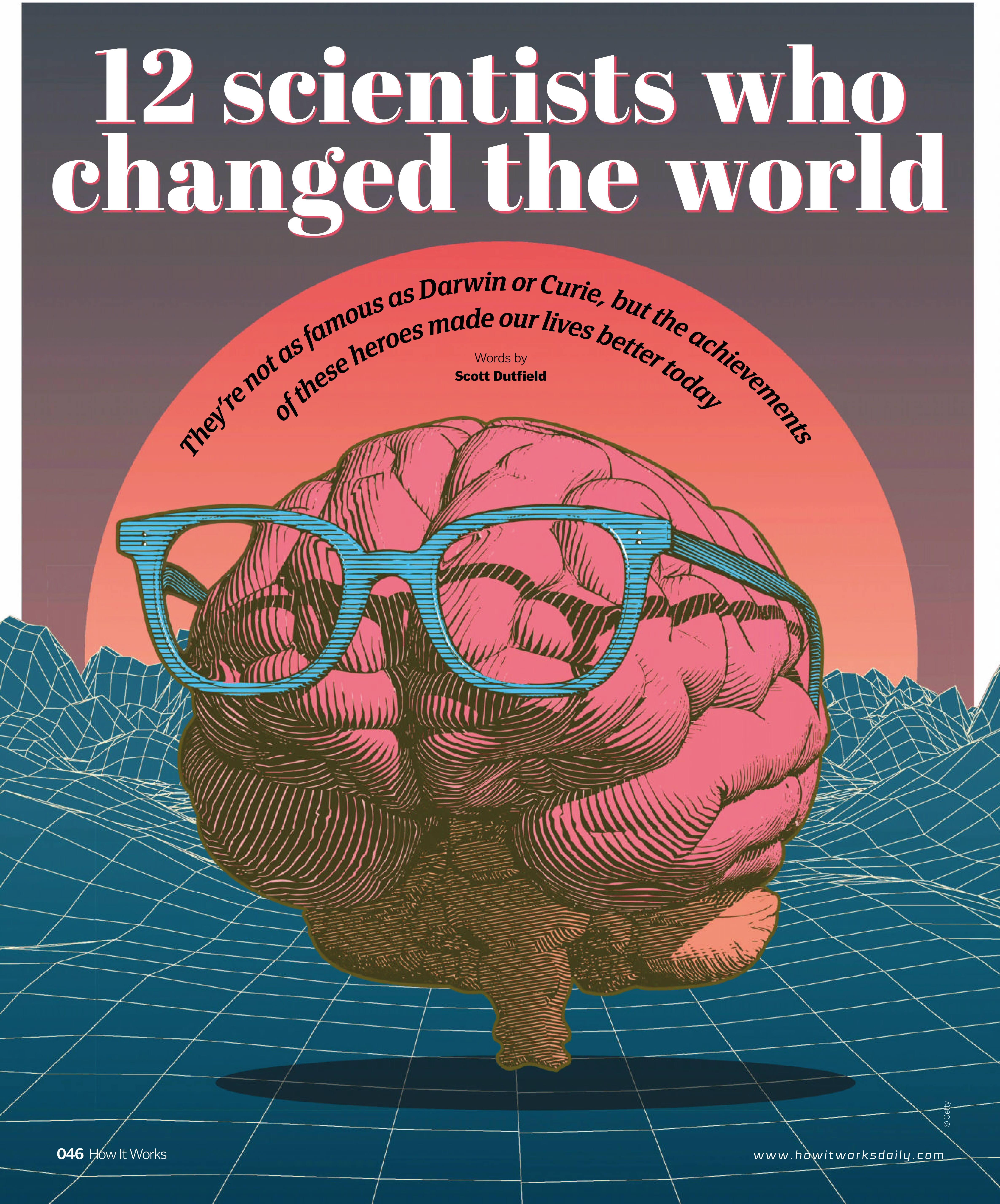
© SpaceX
The Falcon 9 rocket is a cheap and efficient solution for space travel

© SpaceX

12 scientists who changed the world

They're not as famous as Darwin or Curie, but the achievements of these heroes made our lives better today

Words by
Scott Dutfield



© Getty

DID YOU KNOW? *In 1823 Alexander Lucius Twilight was the first African American to graduate from a college in the US*

Zapping cataracts with lasers

Patricia Bath 1942-2019

Sight is one of our most treasured senses, but as we grow older our ability to see can become compromised for a multitude of reasons. One common age-related optical ailment is the development of cataracts. At the forefront of each of our eyes, a glass-like lens allows the image of the outside world to be projected into our brains. As we age the proteins that make up that lens can slowly break down and turn a once crystal-clear lens cloudy. In turn the projected image can no longer be seen in such clarity, but instead appears foggy, or in extreme cases is shrouded in darkness.

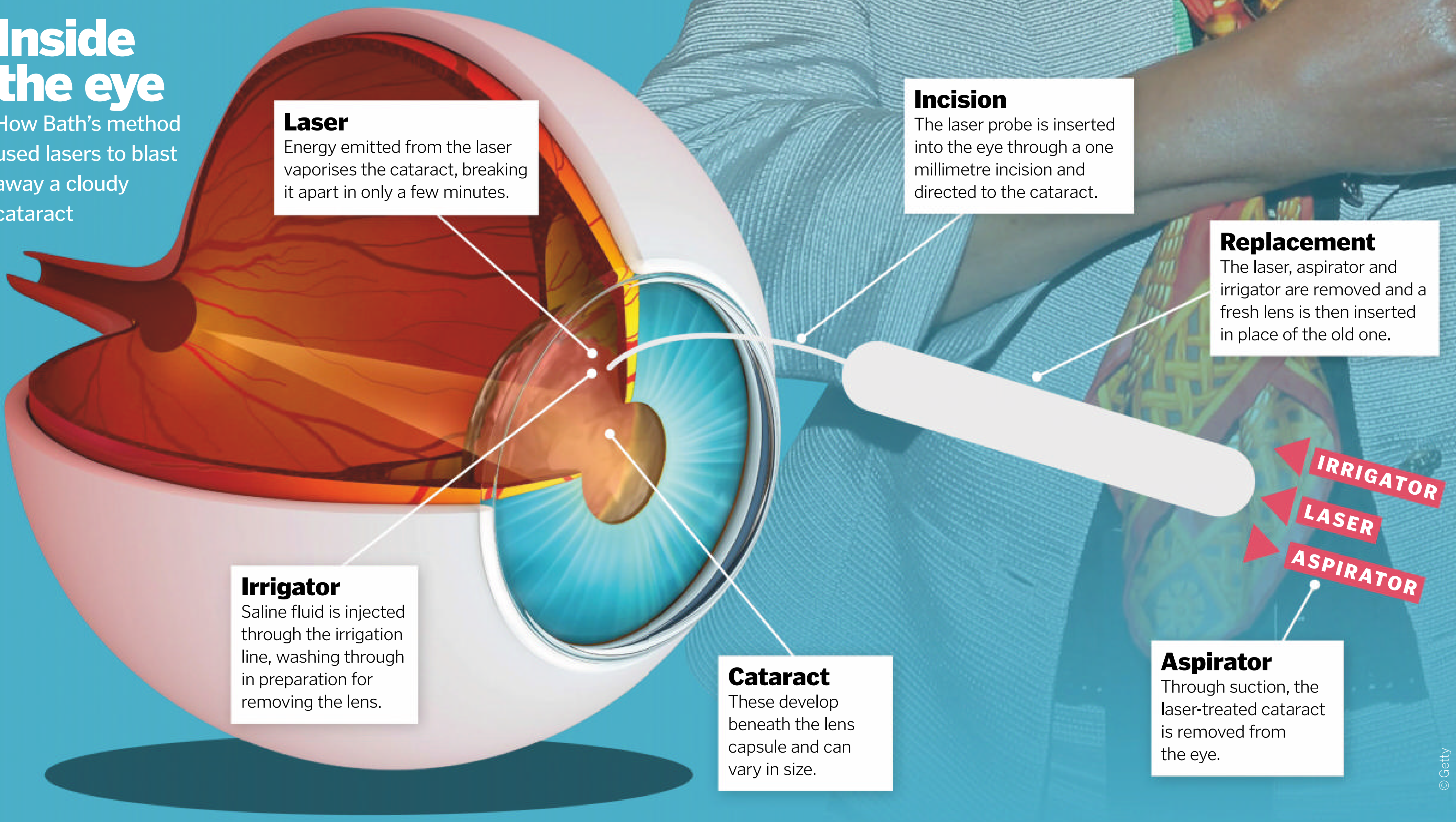
Some form of treatment for the condition has been around since the 5th century BCE. However, over the centuries the methods of removing, replacing and obliterating the cloudy build-up have evolved. One particular medical breakthrough occurred in 1986 after Patricia Bath invented the Laserphaco Probe. Up until then it was common practice to insert a needle into the eye to reach the lens, and then an ultrasound probe was used to break apart the cloudy cataract. However, Bath developed a novel way to remove the cataract using lasers to replace the ultrasound, with the ability to conduct the surgery with greater accuracy and better results. Bath had perfectly demonstrated what was thought to have been impossible in her work, which shocked the scientific community. Two years after the invention of the Laserphaco Probe, Bath gained a patent for her creation, not only cementing herself as a pioneer among ophthalmologists, but also becoming the first African-American female doctor to receive a medical patent.

Patricia Bath was the first African American to complete a residency in ophthalmology, the diagnosis and treatment of eye disorders

© Getty

Inside the eye

How Bath's method used lasers to blast away a cloudy cataract



Laser
Energy emitted from the laser vaporises the cataract, breaking it apart in only a few minutes.

Incision
The laser probe is inserted into the eye through a one millimetre incision and directed to the cataract.

Replacement
The laser, aspirator and irrigator are removed and a fresh lens is then inserted in place of the old one.

Irrigator
Saline fluid is injected through the irrigation line, washing through in preparation for removing the lens.

Cataract
These develop beneath the lens capsule and can vary in size.

Aspirator
Through suction, the laser-treated cataract is removed from the eye.

Revealing the secret of sonic booms

Christine Darden 1942-present

Juggling a full-time job, doctorate degree and raising three children, Darden still managed to pioneer supersonic flight

© NASA

At the dawn of the infamous Space Race between the US and the USSR, which began in 1955, NASA employed a swarm of 'human computers' to calculate flight trajectories, propulsion and rocket dynamics. One of these human computers was Christine Darden, who joined the ranks in 1967. Eight years later Darden sought to apply her mathematical skills to the field of engineering and secured a position at NASA's Langley Research Center as one of a handful of female engineers.

Unbeknownst to Darden, her first assignment would be a groundbreaking one. Sent to work on a project to study sonic boom minimisation, the rollout of modern computers directed Darden to expand her mathematical abilities to design computer programs to calculate the effects of sonic booms. While working on the project full time, Darden also found the time to undergo doctoral courses in mathematical and engineering science at George Washington University in Virginia. For her dissertation she combined her work at NASA to explore the environmental impacts of supersonic transport (SST). When an object such as a plane travels at such a high speed it creates waves of pressurised air, heard on the ground as a sonic boom. These booms can be so violent that they can cause damage to structures below and even shatter glass.

In an attempt to evaluate the risks associated with SST, teams of NASA scientists replicated the booms using wind tunnels, while Darden took to her computer to develop a computer program to calculate the effects of the booms. Comparing Darden's data and model experiments, the two produced the same outcomes, although Darden's method proved cheaper and more efficient than building a model simulation. Unfortunately NASA discontinued the SST project, but Darden's work didn't go to waste. Seeing the potential applications for military aircraft development, Darden completed her sonic boom research, graduating with her engineering doctoral degree in 1983.

Shock waves are created whenever an object travels through the air faster than the speed of sound

© Getty

Invention of the blood bank

Charles Drew 1904-1950

Often referred to as the father of modern-day blood banks, Charles Drew's medical achievements not only advanced our understanding of the blood that flows through our veins, but his medical insights came at a time when the demand for replacement blood was at an all-time high.

Climbing the academic ranks after graduating from the McGill University of Medicine in Montreal in 1933, Drew became the chief surgical resident at Freedman's Hospital before studying at Columbia University where he won a fellowship to train at the Presbyterian Hospital in New York City.

Completing his doctoral degree, Drew was assigned to work under John Scudder, who had been granted funds to work on the first-ever blood bank, but ultimately it would be Drew that designed a technique to make this a reality. Having studied blood chemistry, fluid replacement, transfusion and storage, Drew became a leading expert on all things blood, an attribute especially valued during the carnage of World War II. As Great Britain battled against Nazi Germany the casualties of soldiers on the frontline mounted, and so did the need for blood for transfusions. As an Allied nation the US formed the Blood for Britain Project with an aim to identify a way to successfully ship blood overseas. Drew was appointed head of the project, and alongside Scudder the pair devised a way to separate plasma from blood to be transfused upon arrival in Britain.

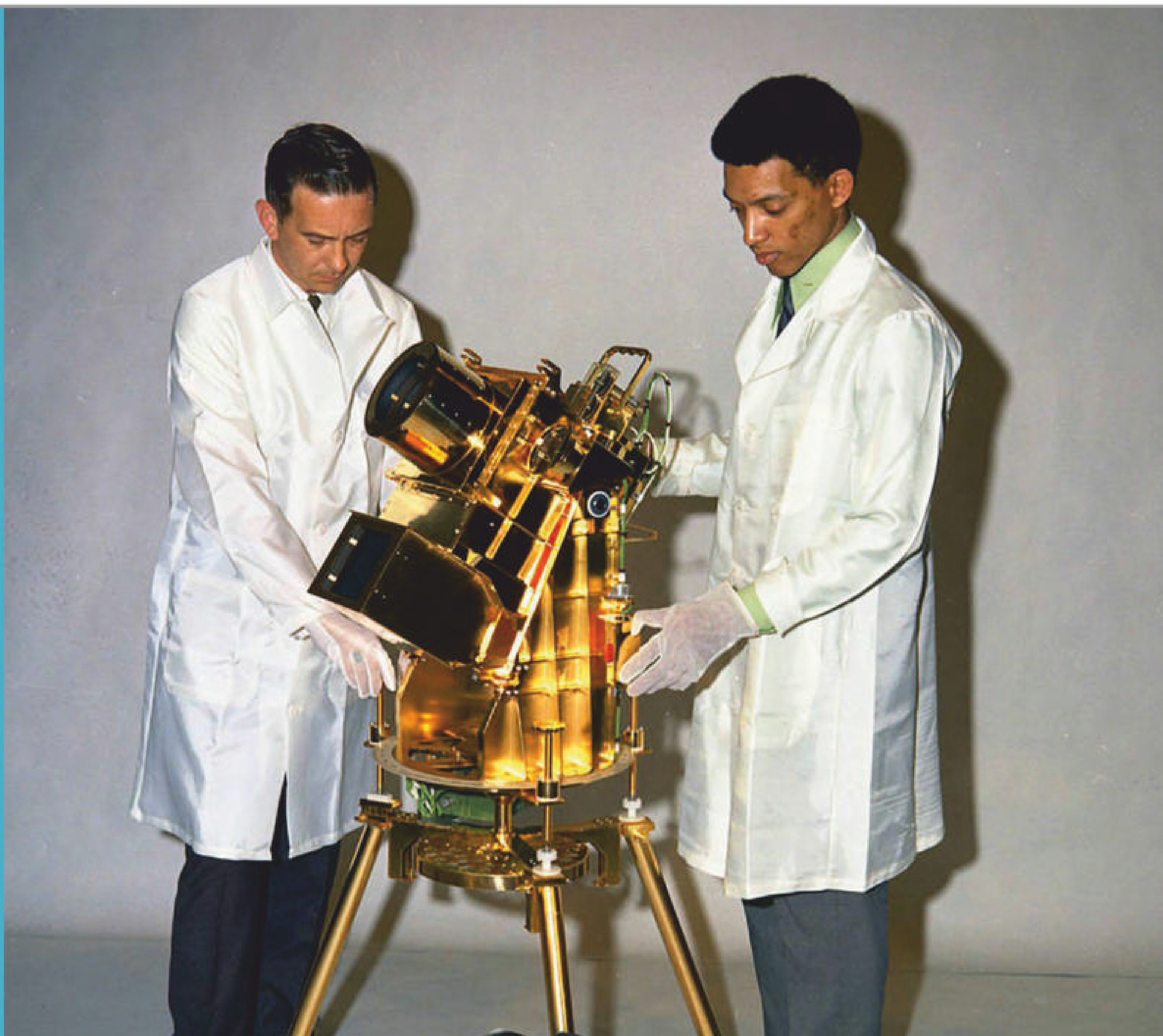
Untreated blood needs to be refrigerated to remain viable, however, and the electrolyte carrying plasma within did not. By splitting the plasma from the blood and mixing it in a saline solution, it could be shipped abroad without refrigeration and remain viable for transfusions. Plasma could also be used regardless of the blood type of the patient that would be receiving it. By 1941 the Blood for Britain project had collected 14,556 blood donations, shipping over 5,000 litres of plasma to England.

DID YOU KNOW? *In 1957 Chinese physicists Tsung-Dao Lee and Chen Ning Yang won the Nobel Prize in Physics*

World's first lunar telescope

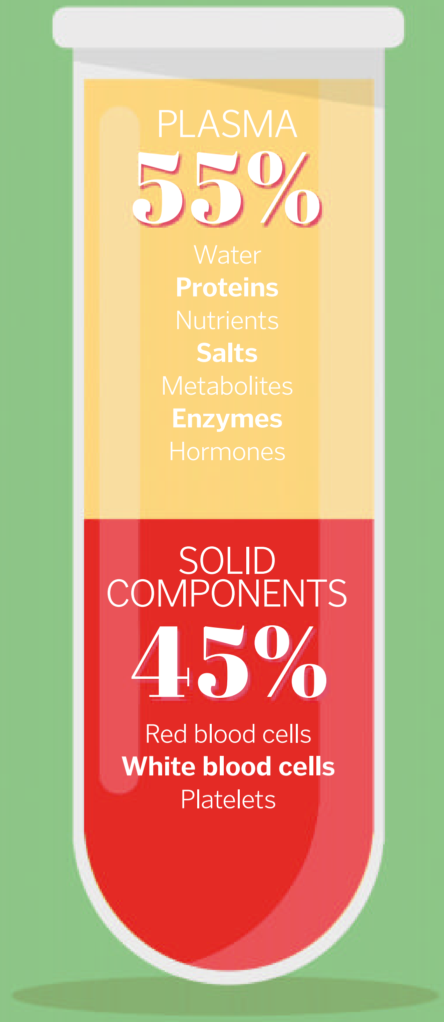
George Carruthers 1939-present

Back in 1972, scientist George Carruthers opened humanity's eyes to the universe around us through the lens of his 'Lunar Surface Ultraviolet Camera'. In 1969 Carruthers was awarded the patent for the device previously known as the 'Image Converter for Detecting Electromagnetic Radiation Especially in Short Wavelengths'. To put it in a nutshell, Carruthers' invention could observe Earth's atmosphere from the Moon and take a glimpse at neighbouring stars and nebulae based on the radiation they emit. Shipped aboard the tenth crewed mission to the Moon, Apollo 16, once placed on the lunar surface the camera took more than 550 ultraviolet images of stars across the cosmos, nebulae and unknown galaxies. Carruthers' creation also collected data on Earth's atmosphere and the concentration of pollutants in the atmosphere.



Carruthers (right) examining the ultraviolet camera/spectrograph that became the first Moon-based observatory

© U.S. Naval Research Laboratory



Drew's method of separation

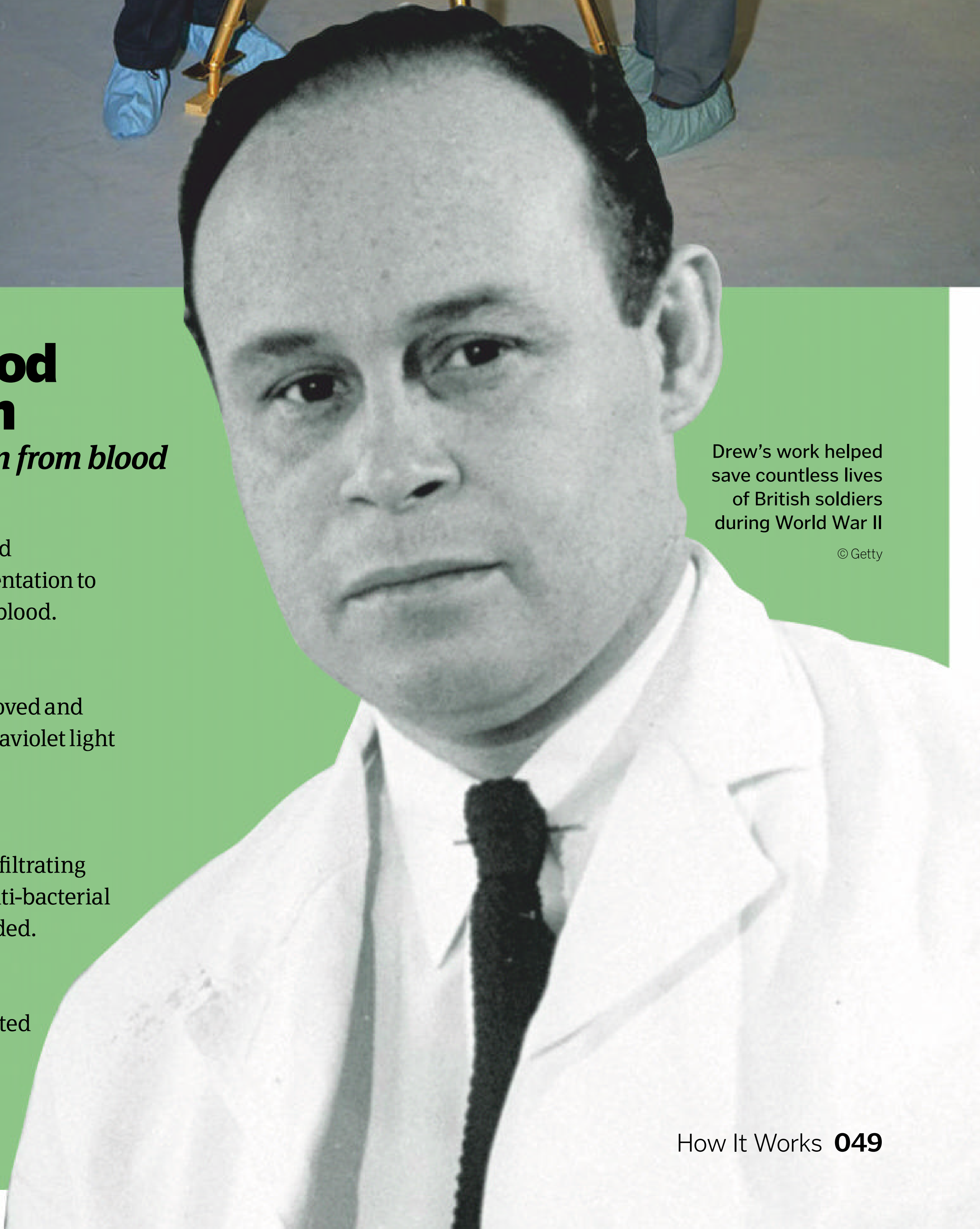
How plasma was taken from blood

1 Separation Drew and his team used centrifugation and sedimentation to separate plasma from the blood.

2 Extraction Plasma was then removed and pooled together under ultraviolet light to prevent contamination.

3 Bacteria To prevent bacteria infiltrating the batches of blood, an anti-bacterial called Merthiolate was added.

4 Storage Plasma was then diluted with saline solution and sealed for shipping.



Drew's work helped save countless lives of British soldiers during World War II

© Getty

Curing leprosy

Source: Wiki Commons

Alice Ball 1892-1916

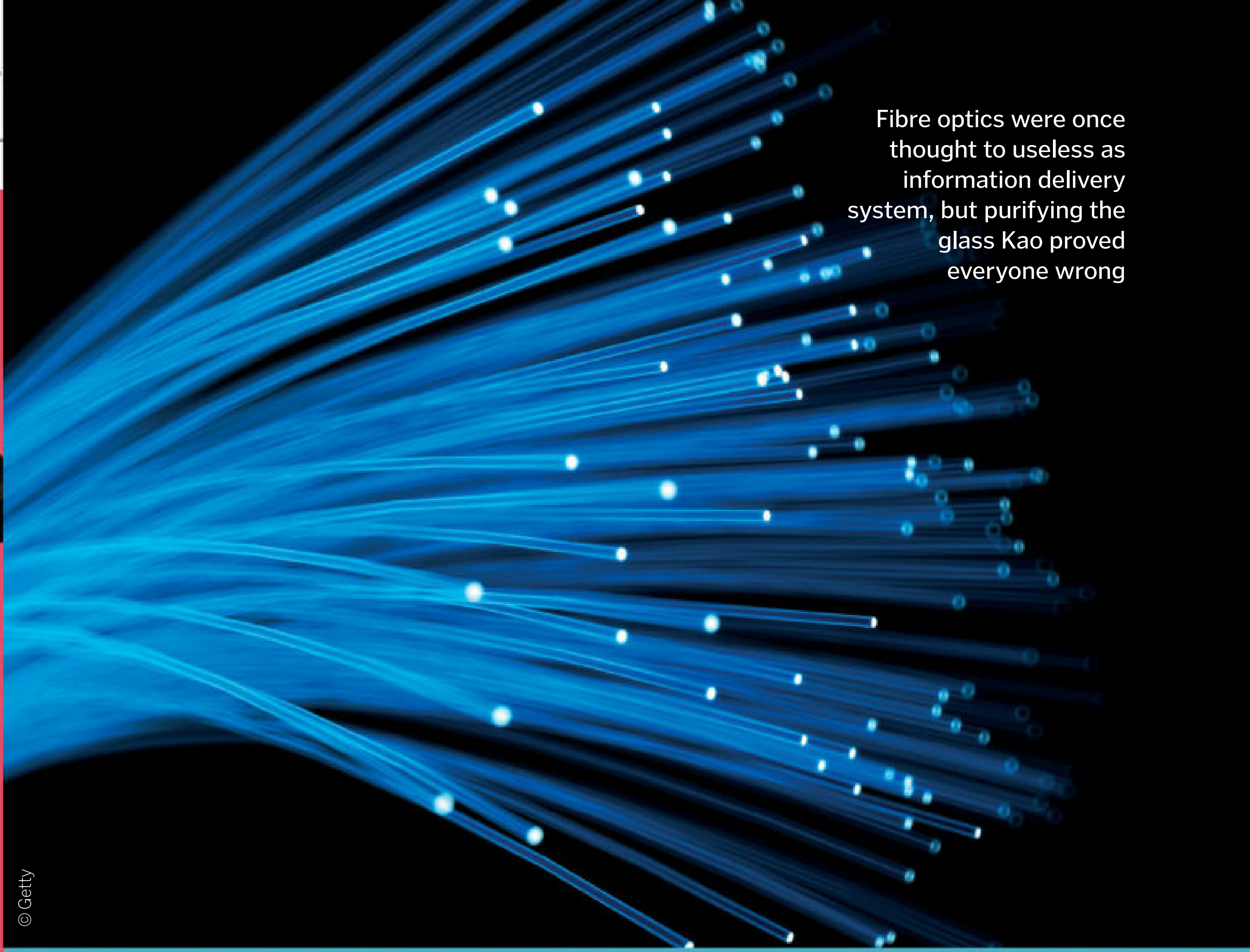
Long before Alice Ball was born, leprosy – or Hansen's disease as it was then known – wreaked havoc on the health of people around the world, causing nerve damage and skin lesions. A bacteria called *Mycobacterium leprae* was discovered to be the culprit in 1873 by Norwegian physician Dr Gerhard Henrik Armauer Hansen. The first treatment for the condition was to use oil from a chaulmoogra nut, applied as a topical treatment, ingested or even injected. Although patients that underwent this treatment showed improvements, the long-term side effects arguably outweighed the benefits, with bruises beneath the skin and nausea replacing the symptoms of leprosy. That was until Alice Ball stepped in with a revolutionary new method of treatment.

Ball had made waves during her academic career, becoming the first African-American and the first woman to graduate with a master's degree in chemistry from the University of Hawaii. Having caught the eye of Dr Harry Hollmann, an assistant surgeon at Kalihi Hospital, a treatment centre for leprosy patients, Ball began working on a new way to isolate the active ingredient in the oil. Focusing on a method to extract the medically beneficial compounds from chaulmoogra as opposed to using the oil in its entirety, Ball engineered a water-soluble injection as an alternative treatment, one that would be used until the 1940s.

Sadly Ball died at the age of 24 before her work could be published, and so credit for her revolutionary method was attributed to colleague and college president Arthur L. Dean, who neglected to mention Ball's involvement in the 'Dean Method'. Justice for Ball's exemplary work, however, came when Hollmann credited the scientific advancement as the 'Ball Method'.

Source: Wiki Commons/Anoopmail

Chaulmoogra (*Hydnocarpus wightianus*) is an evergreen tree found commonly in the rainforests of South India



Fibre optics were once thought to useless as information delivery system, but purifying the glass Kao proved everyone wrong

© Getty

Bringing broadband to the masses

Charles Kuen Kao
1933-2018

Known as the father of fibre-optic communication, Charles Kuen Kao revolutionised the way we benefit from a high-speed internet connection. In the mid-1960s Kao proposed a method of information delivery, in the form of light, through fibre-optic cables. The cables consisted of a long glass pipe along which light beams would be fired. You might imagine that light simply shines through the glass and escapes. However, Kao used purified glass in such a way that the wall of the pipe acted as a mirror for the light photons, allowing them to bounce within and continue travelling down the pipe, a phenomenon called total internal reflection. This results in the light information being transmitted across far-flung distances, perfect for telecommunications.

Born in Shanghai, China, Kao later moved to England, completing an electrical engineering doctorate at the University of London in 1965

© Getty

Cracking HIV's genetic code

Flossie Wong-Staal 1946-2020

Moving to California from Hong Kong at the age of 18, Flossie Wong-Staal studied bacteriology at the University of California, graduating in 1968 and gaining a doctoral degree in molecular biology four years later.

Taking her acquired knowledge to the National Cancer Institute in Maryland in 1973, Wong-Staal became one of the team members to first discover the cause of human immunodeficiency virus (HIV). It was disputed by a team in France who had coincidentally discovered the cause at the same time. However, Wong-Staal's rise to academic distinction came when she became the first person to successfully clone HIV.

Unlike other viruses, the transmission of HIV cannot be prevented with a one-size-fits-all vaccine, suggesting to Wong-Staal that there might be a genetic element to the way it worked. Of course, she was right, allowing her to artificially clone the virus and genetically map it, in turn paving the way for the development of modern-day treatments and the creation of blood tests to detect the virus in patients.

HIV attacks essential immune system cells called T lymphocytes

Source: Wiki Commons

MEDICAL MILESTONES

Source: Wiki Commons

Daniel Hale Williams

Williams became the first cardiologist to successfully perform a repair of the pericardium – the sac around the heart – during an open-heart surgery in 1893.

Source: Wiki Commons

Ernest Everett Just

Just conducted pioneering research in embryonic development and fertilisation. His groundbreaking work revealed the importance of the cell surface in cell development.

© Getty

Percy Lavon Julian

Julian's revolutionary work with plants led him to pioneer a process of synthesising drugs. In 1935 Julian was the first to synthesise physostigmine from Calabar beans to treat glaucoma.

Source: Wiki Commons

Marie Maynard Daly

The first African-American woman to be awarded a PhD in chemistry in the US, Daly made the discovery of the relationship between high cholesterol and clogged arteries.

Source: Wiki Commons

Har Gobind Khorana

India-born Khorana became the first person to synthesise an artificial gene from a living cell. Cracking the genetic code, Khorana revealed the role of nucleotides in protein synthesis.

Inside the White House bunker

Words by **Ailsa Harvey**

Where can the president go for ultimate protection?

Looking at the White House, it's easy to become envious of the lifestyle that comes with being the president of the United States of America. But this role comes with a target on your back. The president is unable to travel anywhere, step outside their house or even sleep in their own bed without security technology and personal guards.

Recently Donald Trump disappeared from the White House building as protests outside intensified. But where did he go? The answer lies beneath the East Wing of this mighty home, in the form of an underground bunker.

Built during World War II for President Franklin D. Roosevelt, the first White House bunker was deemed essential following the 1941 Pearl Harbour attack. Since then a more modern and secure version has replaced it. An evacuation to the safety of the bunker was made by senior officials during the 9/11 attacks on the World Trade Center. Before this disaster the preferred option was always to escort the president out of the area before retreating below ground. However, in this case it became a concern that there wouldn't be enough warning given of an attack to execute this escape plan. Predictably, many of the details of this bunker are top secret, but here's what is known about this mysterious hideaway.

The White House's extensive security team watch all areas of the building for outside threats

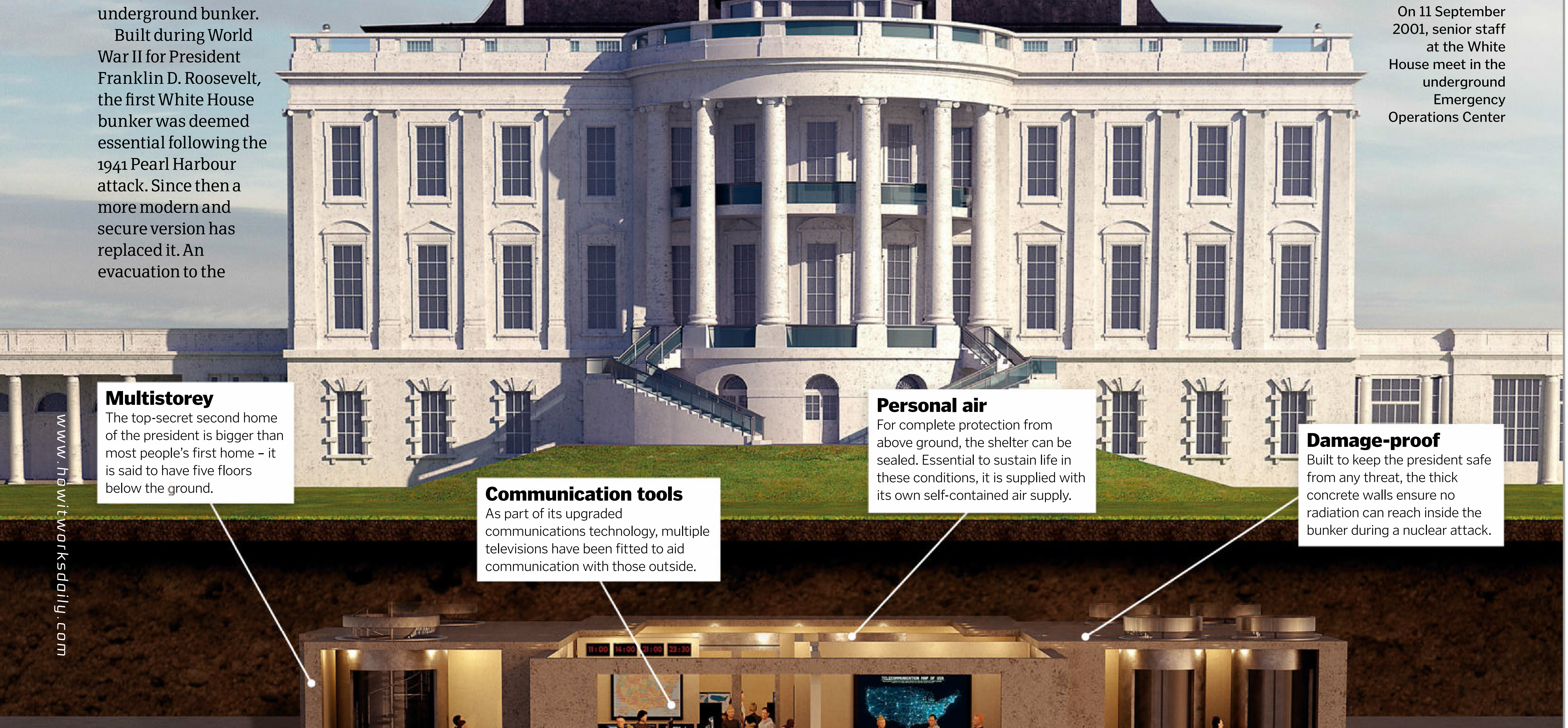
© Getty

On 11 September 2001, senior staff at the White House meet in the underground Emergency Operations Center

© The US National Archives

Subterranean living

The underground retreat needs to keep occupants secure, happy and healthy for a potentially lengthy stay



Multistorey
The top-secret second home of the president is bigger than most people's first home – it is said to have five floors below the ground.

Communication tools
As part of its upgraded communications technology, multiple televisions have been fitted to aid communication with those outside.

Personal air
For complete protection from above ground, the shelter can be sealed. Essential to sustain life in these conditions, it is supplied with its own self-contained air supply.

Damage-proof
Built to keep the president safe from any threat, the thick concrete walls ensure no radiation can reach inside the bunker during a nuclear attack.

FIVE PRESIDENTIAL SECURITY FEATURES

1 Infrared alert
Lasers cover the entire perimeter of the White House, detecting any trespassers from the sky to the ground.

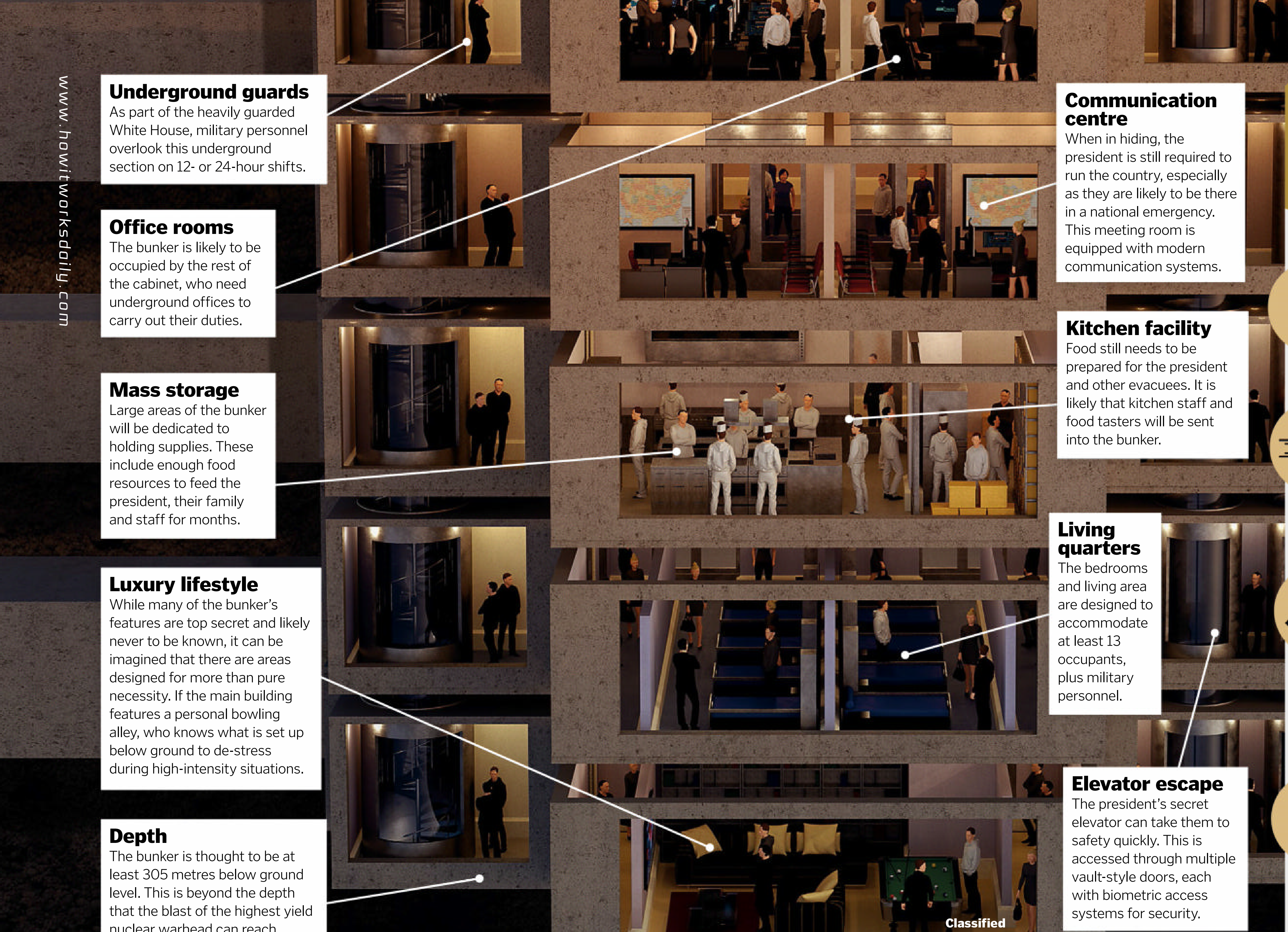
2 Bulletproofing
The building's 147 windows may seem like a safety flaw, but all of these are actually made of extremely thick bulletproof glass.

3 Rooftop teams
The sky above the White House is a no-fly zone. Any planes that fly over and do not react to warnings are exposed to the building's missile systems. A rooftop team of guards keep lookout, armed with sniper rifles.

4 Food testers
Some threats don't require evacuation to a bunker. To avoid presidential poisoning, a food tester tries all the food before it reaches the president's mouth.

5 Secret alarms
Alarms are needed to alert security of any danger within the building. At the president's desk there is believed to be a secret alarm that can be pressed if an intruder makes it in.

AR ZONE! SCAN HERE



Underground guards
As part of the heavily guarded White House, military personnel overlook this underground section on 12- or 24-hour shifts.

Office rooms
The bunker is likely to be occupied by the rest of the cabinet, who need underground offices to carry out their duties.

Mass storage
Large areas of the bunker will be dedicated to holding supplies. These include enough food resources to feed the president, their family and staff for months.

Luxury lifestyle
While many of the bunker's features are top secret and likely never to be known, it can be imagined that there are areas designed for more than pure necessity. If the main building features a personal bowling alley, who knows what is set up below ground to de-stress during high-intensity situations.

Depth
The bunker is thought to be at least 305 metres below ground level. This is beyond the depth that the blast of the highest yield nuclear warhead can reach.

Communication centre
When in hiding, the president is still required to run the country, especially as they are likely to be there in a national emergency. This meeting room is equipped with modern communication systems.

Kitchen facility
Food still needs to be prepared for the president and other evacuees. It is likely that kitchen staff and food tasters will be sent into the bunker.

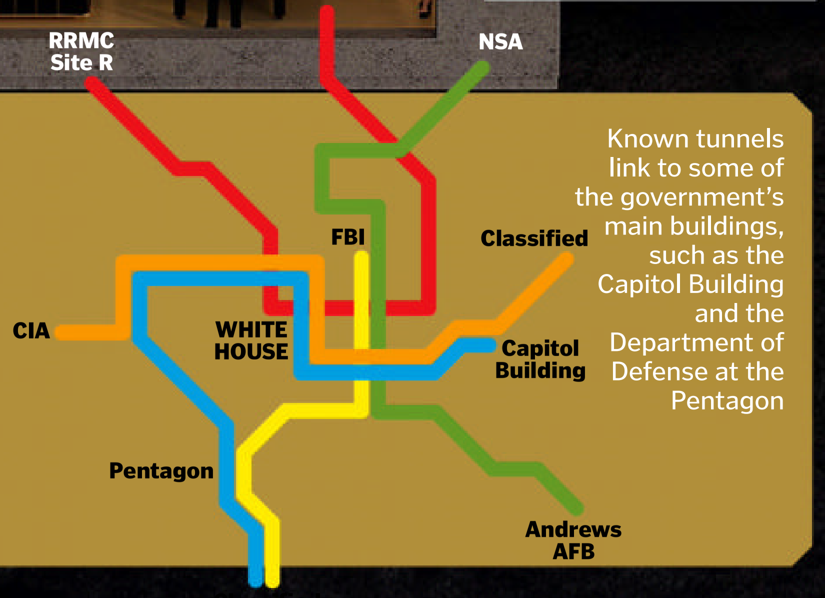
Living quarters
The bedrooms and living area are designed to accommodate at least 13 occupants, plus military personnel.

Elevator escape
The president's secret elevator can take them to safety quickly. This is accessed through multiple vault-style doors, each with biometric access systems for security.

Tunnel network

Escaping into a restricted bunker may make it sound like the president is being desperately backed into a hole in the ground. However, this does not mean he is trapped. Underground there's a maze of tunnels, emerging in different surrounding locations. Should a resurfacing be needed while the White House is unsafe, a choice of secret routes can transport the president out of sight from surface onlookers.

While the whereabouts of many of these tunnels remain classified, some are well known. One discreet entrance to the White House is found on H Street in Washington. Though only a couple of blocks away, when passing by it's hard to believe this regular alleyway with a seemingly low-key vehicle gate could lead to the grandest building in the country.



Known tunnels link to some of the government's main buildings, such as the Capitol Building and the Department of Defense at the Pentagon

© Illustration by Nicholas Forder

How American women won the vote

© Getty

100 years ago, after decades fighting for suffrage, women in the US were given a voice

Words by **Ailsa Harvey**

Voting gives us a voice. It allows us to express our beliefs, act on our views and have a say in matters that will impact the way we live. In America today, everyone over the age of 18 can vote, but many take this for granted. For women this was not always the case.

Partaking in an election was an unlikely ambition for many, and some women dedicated their lives to turning this into a reality. When the 19th Amendment was ratified in 1920, everybody in the country was guaranteed the right to vote, regardless of their sex. Before this American women were made to abide by laws which they could not vote for or against. They were treated as inferior to men, with irrational rules telling them what they could and couldn't do. Their position in society was so fixed that many women had simply accepted their place.

While there was so much women were forbidden from doing, there were some who believed they could bring about change. This is the story of those who fought relentlessly for equality at a time when the odds were not in their favour. These are the people who gave every woman after them the voice and rights that they were forced to live without.

The battle to the ballot box

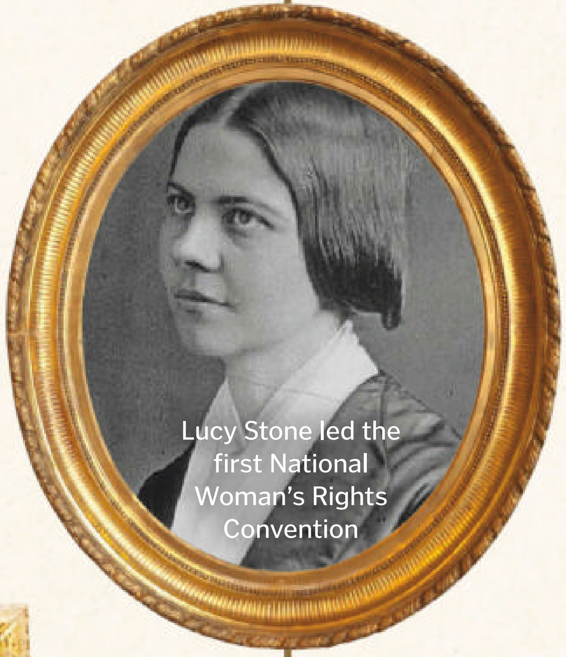
19-20 JULY 1848

First convention

The Seneca Falls Convention was the first for women's rights in the US. This event, held in New York, saw the attendance of 300 people, who were mainly local. Among the issues of equality in jobs, religion, education and politics, they debated the issue of having to follow laws dictated by men. This convention gained press coverage and recognition across the US and became a regular and more popular affair over the years.

The first day was women-only, and the second was open to men

© Source: wiki commons



Lucy Stone led the first National Woman's Rights Convention

23-24 OCTOBER 1850

National Woman's Rights Convention

The first of these annual meetings took place in Worcester, Massachusetts. This was led by both men and women and drew in a crowd of over 1,000 people. Paulina Wright Davis addressed the crowd, saying: "It is one thing to issue a declaration of rights, but quite another thing to commend the subject to the world's acceptance." This gathering took place every year for the next decade – with the exception of 1857 – to try to apply this equality.

MAY 1866

American Equal Rights Association forms

This association aimed for equal rights for all American citizens. While especially focused on votes for women at this time, it also tackled inequality based on race. They made a pledge at the 11th National Woman's Rights Convention to achieve suffrage for women of all races.

19 NOVEMBER 1868

Demonstrations begin

During the presidential election, women were expected to sit back and let the men decide who would run the country. However, in New Jersey 172 women voted anyway, bringing their own ballot box with them. Although their votes still weren't counted, by voting in a separate box their votes acted as a powerful demonstration.

DID YOU KNOW? 50 years before the rest of the United States, Wyoming gave women the vote

“Many women had accepted their place”

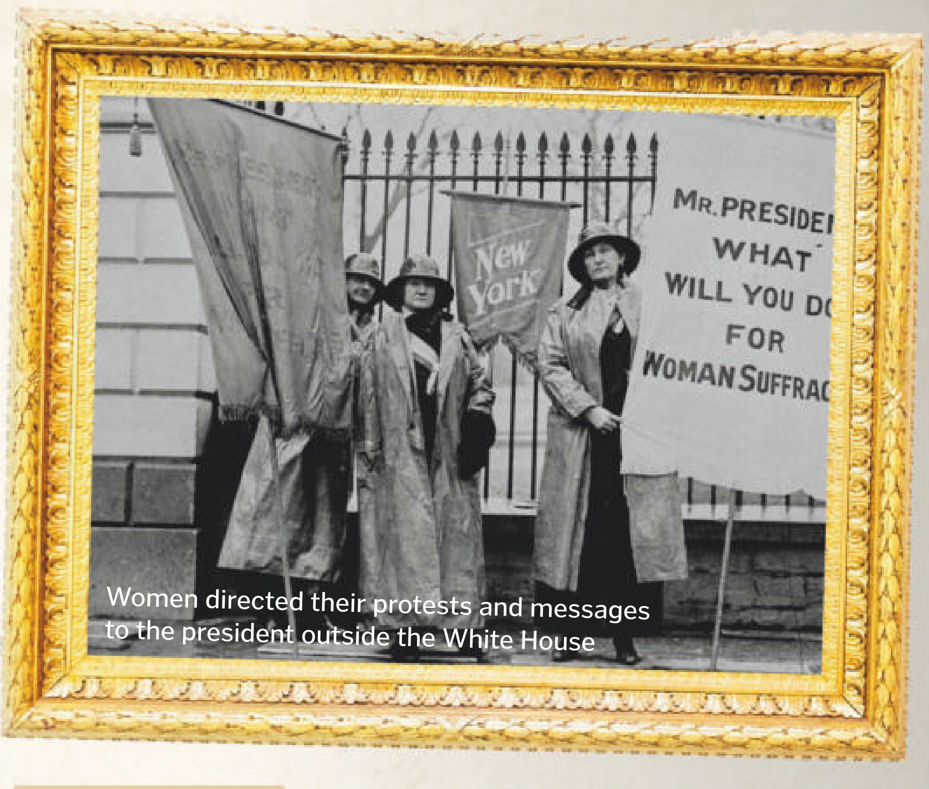
1910

First large-scale parade

On the streets of New York City, hundreds of women took to the streets in a parade of protest that would soon rise to thousands of participants each year. This proved hugely successful in publicising the issue and recruiting more protesters. The parade was even given official city permission to become a recurring event.

© Alamy

Crowds lined the streets of New York during the 1913 suffrage parade

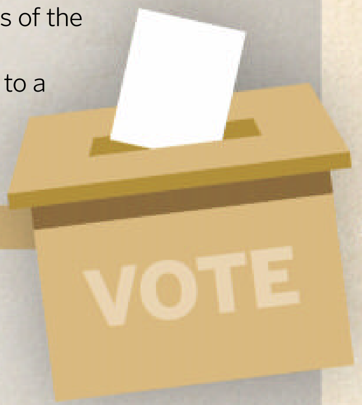


Women directed their protests and messages to the president outside the White House

9 JANUARY 1918

Presidential support

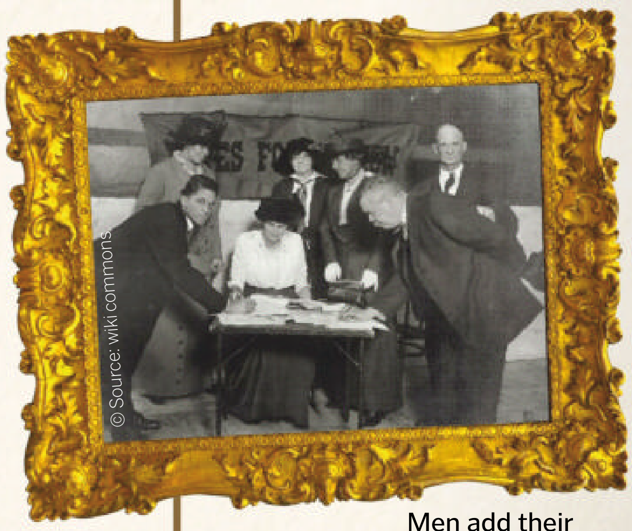
Having succeeded in capturing the president’s attention, he finally announced his support for women’s suffrage. The next day the House of Representatives voted, with two-thirds in favour of the amendment. When later addressing the Senate, it became clear that the president’s opinion of women had changed significantly due to their vital roles in World War I. As part of his speech he said: “We have made partners of the women in this war… shall we admit them only to a partnership of suffering and sacrifice and toil, and not to a partnership of privilege and right?”



1890

Society plan

Following the merging of the American Woman Suffrage Association and the National Woman Suffrage Association, the National American Woman Suffrage Association was formed. The group’s new president put in place a structure to recruit more privileged members. The thought was that this would increase their status, but this led to racial inequality within the groups, a step backwards in the aim to grant women of all races equal voting rights.


© Source: wiki commons

Men add their signatures to a women’s suffrage petition in 1916

2 DECEMBER 1916

Petition dropping

With thousands of petition signers on board, how do you make sure the president pays attention to your efforts? Activists in 1916 discovered one way to do this was to literally drop petitions onto President Woodrow Wilson. The way they achieved this was by flying over his yacht armed with their well-earned signatures. A month later the National Woman’s Party protested in front of the White House for six days a week, standing their ground in the face of violence from the public, police arrests and bad weather.

© Source: wiki commons

The National American Woman Suffrage Association headquarters

26 AUGUST 1920

Women gain the vote

After states across the US had introduced the new law one by one, it was on this day that the 19th Amendment was signed into law. This amendment guaranteed every American woman in every state the right to vote. While some of the early activists never got to live to see the success of what they began, this victory meant that their strength and determination was not in vain, and that American women would no longer have to live by the laws dictated to them by men.

The ratification banner is hung from a balcony to celebrate the passing of the 19th Amendment

5 SUFFRAGE SPEAKERS

1 Sojourner Truth

As an African-American woman who was owned as a slave for around 28 years, Sojourner Truth had known a life of inequality. The speech she made at the 1851 Woman’s Rights Convention became her most famous, proving what women are capable of. She said: “Look at me! Look at my arm! I have ploughed and planted… and no man could head me. And ain’t I a woman?”

2 Elizabeth Cady Stanton

While at an anti-slavery convention in 1840, Stanton met Lucretia Mott; together they planned to organise a women’s rights convention. It was this pair who organsied the Seneca Falls Convention eight years later. At this event, Stanton addressed the crowd: “Man cannot speak for us because he has been educated to believe that we differ from him so materially that he cannot judge of our thoughts, feelings and opinions by his own.”

3 Susan B. Anthony

After she was arrested and fined $100 for voting in the 1872 presidential election, Anthony made a speech explaining she had not committed a crime, but “exercised [her] citizen’s rights”. She continued to express that it was “a downright mockery to talk to women of their enjoyment of the blessings of liberty while they are denied the use of the only means of securing them… the ballot”.

4 Emmeline Pankhurst

“I am here as a person who, according to the law courts of my country, it has been decided, is of no value to the community at all.” These were the words spoken by Pankhurst, leader of the Women’s Social and Political Union in the UK. She travelled to Connecticut to address an audience in November 1913.

5 Anna J. Cooper

In 1893 at the World’s Congress of Representative Women, Cooper spoke of women’s ability to put aside their differences to win rights they were all entitled to. In her speech she said: “[Not till] the pursuit of happiness is conceded to be inalienable to all; not till then is a woman’s lesson taught and a woman’s cause won – not the white woman’s, nor the black woman’s, not the red woman’s, but the cause of every man and every woman who has writhed silently under a mighty wrong.”

© Getty

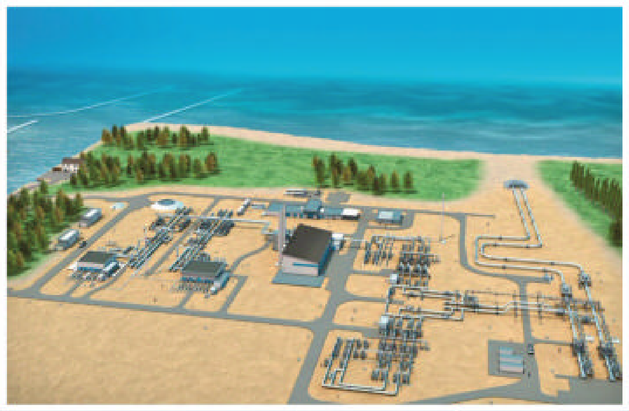
MEGA PIPES

The Nord Stream gas pipeline is an epic structure that offers a glimpse at the advanced engineering needed to fuel the modern world

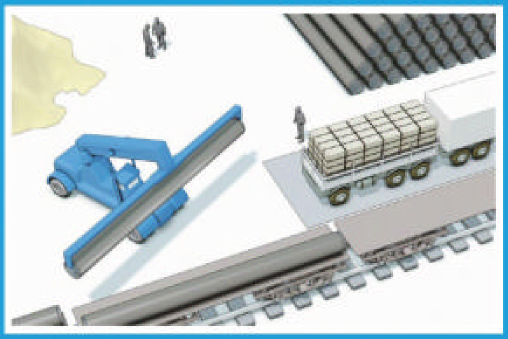
Right now the planet's demand for energy is growing at an exponential rate. Each year more people are born and more homes are built to accommodate them, with each new property needing to be supplied with electricity and gas. This hunger for energy is ravenous, and looking forward it seems to show no signs of abating.

To combat this ever-rising need for power, creative new energy-generating technologies are being implemented, many with renewability at their heart. Progress has and is already being made in this pursuit, with wind farms, marine turbines and solar power stations increasingly contributing to national energy grids. This is undoubtedly the best way forward for our warming planet. Unfortunately though, right now the demand for energy far outweighs that being inputted by renewable sources, with a very real deficit needing to be addressed.

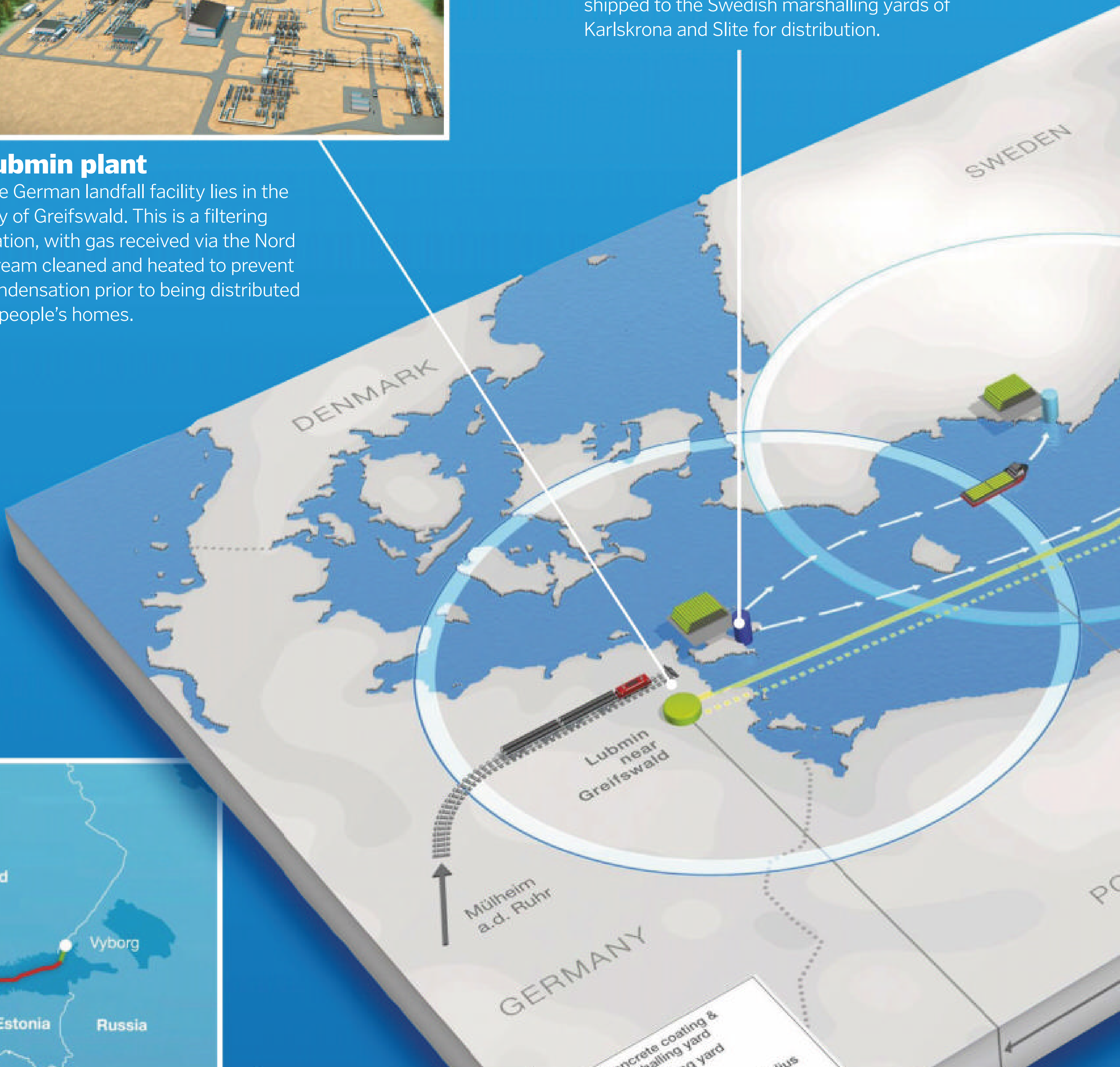
For Europe that deficit is being met by the Nord Stream twin pipeline system, a 1,224-kilometre pair of gas pipes running along the bottom of the Baltic Sea. The pipeline links northwest Russia with northeast Germany and has the capacity to

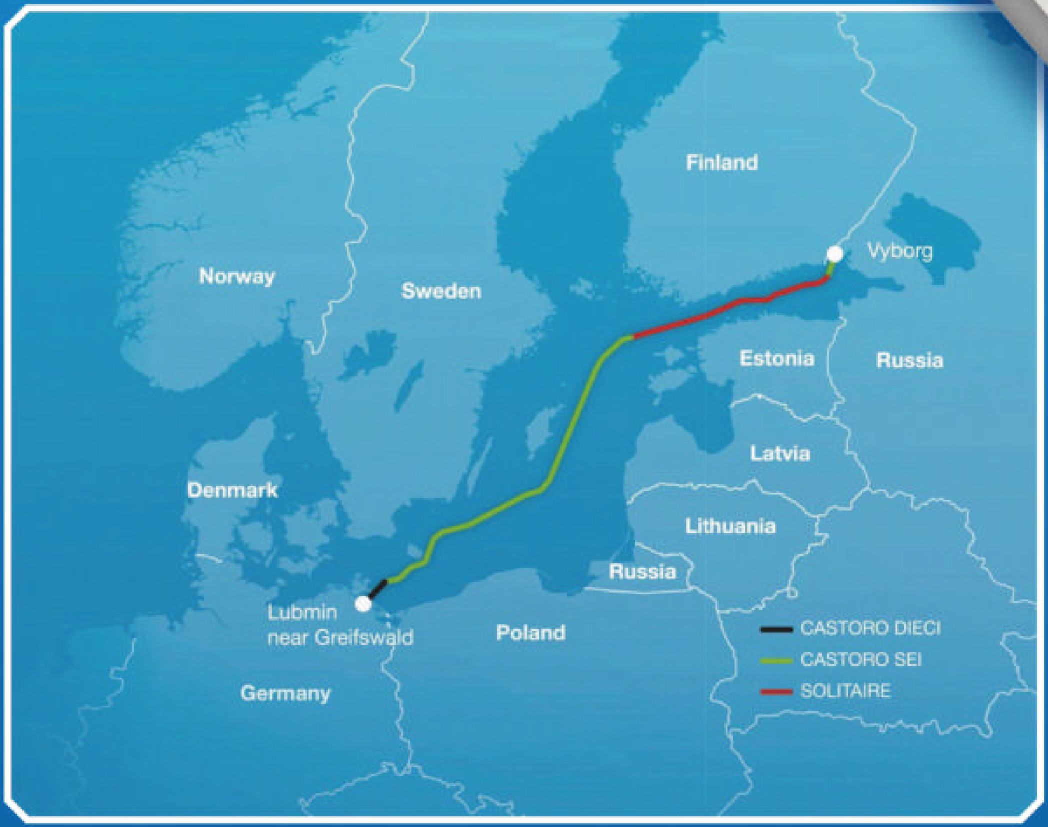


Lubmin plant
The German landfall facility lies in the Bay of Greifswald. This is a filtering station, with gas received via the Nord Stream cleaned and heated to prevent condensation prior to being distributed to people's homes.



Mukran facility
The Mukran facility receives raw materials for the pipeline by rail, including cement, magnetite, sand and aggregate. These are shipped to the Swedish marshalling yards of Karlskrona and Slite for distribution.





The statistics

Nord Stream

Length: 1,224 kilometres

Pipe segments: 199,755

Diameter of pipe: 1.153 metres

Pipe segment weight: 24 tonnes

Lifetime: 50+ years

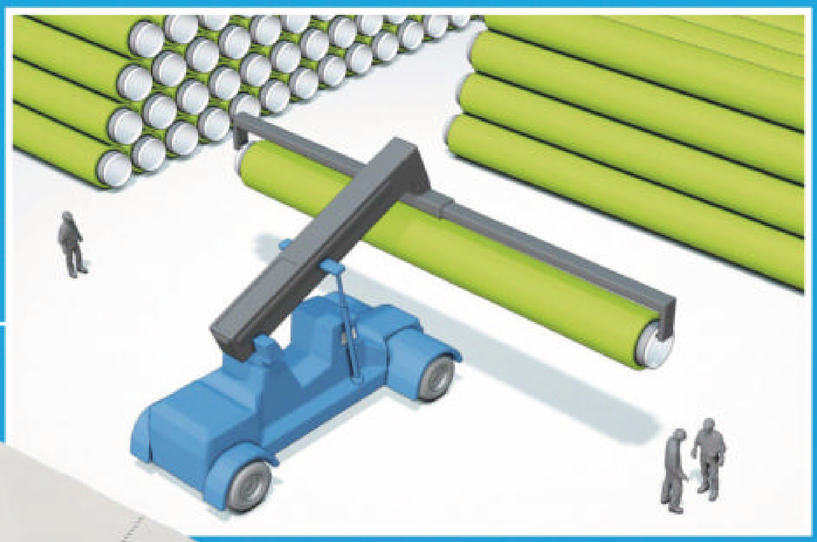
Houses fuelled: 26 million

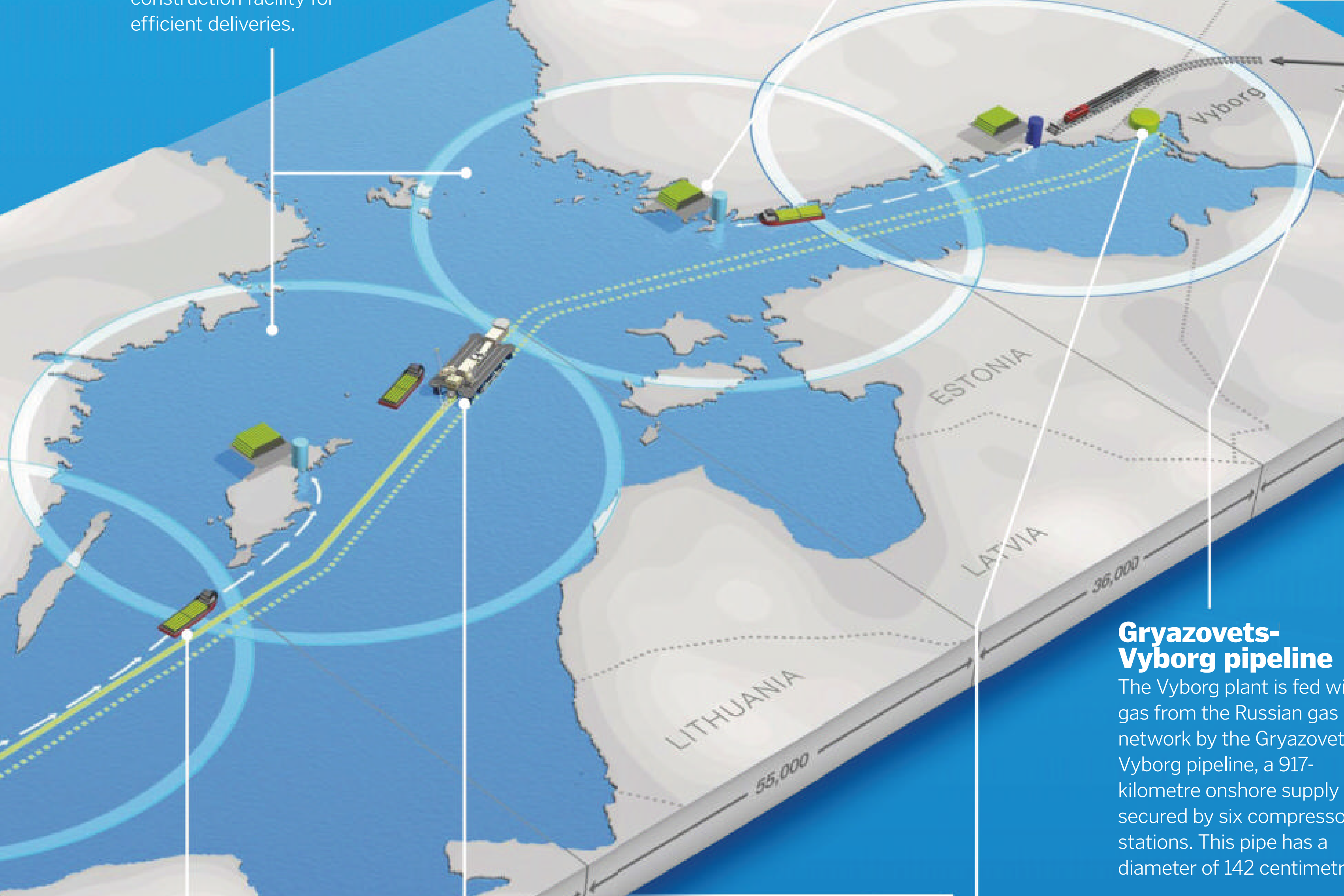
A tour of the Nord Stream

Discover the core facilities along the route of the pipeline and how the various stages were assembled

Operational zones
The Nord Stream is split into five overlapping operational zones, each with a dedicated marshalling yard and/or construction facility for efficient deliveries.

Marshalling yard
As well as the Kotka and Mukran facilities there are three other marshalling yards along the route, located at Karlskrona and Slite in Sweden, and Hanko in Finland. Pipes and materials are stored here for distribution by tankers.

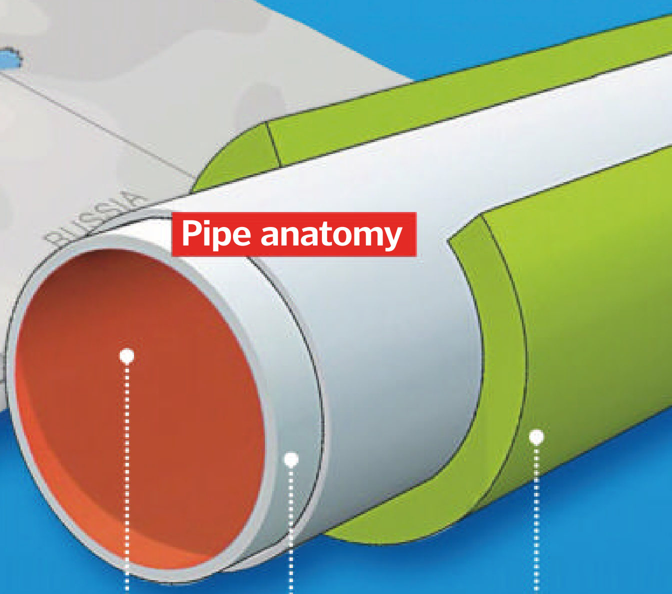




Gryazovets-Vyborg pipeline
The Vyborg plant is fed with gas from the Russian gas network by the Gryazovets-Vyborg pipeline, a 917-kilometre onshore supply line secured by six compressor stations. This pipe has a diameter of 142 centimetres.

Vyborg plant
The Russian landfall facility in Portovaya Bay near Vyborg receives gas from the Russian gas network and compresses it to adequate pressure for transportation via the Nord Stream to Germany.

Pipe anatomy



Within the corrosion-resistant layer lies the pipe's 27 to 41 millimetre thick steel cylinder.

Each pipe segment is surrounded by a 60 to 110 millimetre thick concrete coating.

The inner face of the steel cylinder is coated with an anti-friction layer.

Lay barge
Pipes from the carrier ships are installed by vast lay barges. These colossal vessels measure up to 397 metres in length, needing to carry hundreds of pipes at any one time as well as the range of machinery required to lay them.

Carrier vessel
Concrete pipes from the marshalling yards and Kotka and Mukran facilities are delivered to the Nord Stream's three lay barges on huge carrier vessels. These ships can transport hundreds of pipes on each journey.

The lay barge fleet

Castoro 10 (165 metres)
The Castoro Dieci laid pipes in the German waters around the Lubmin region.

Castoro Sei (193 metres)
The Castoro Sei laid pipes in Swedish, Finnish, Russian, German and Danish waters.

Solitaire (397 metres)
One of the world's largest pipe-laying ships worked in Finnish and Russian waters.

transport up to 55 billion cubic metres of natural gas per year from the gas fields of Siberia directly into the heart of Europe. A second pipeline, Nord Stream 2, will double that capacity. Though it was expected to be operational this year, US sanctions have put a hold on construction.

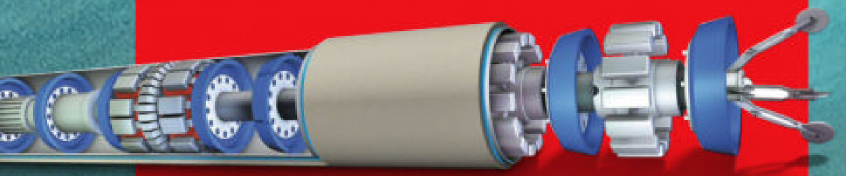
As you might expect, the pipeline is not without its critics. With a life span in excess of 50 years, the Nord Stream will see non-renewable energy continuing to be spent for the foreseeable future, and due to the pipeline's large capacity at an increased rate. In addition, due to the pipeline passing through 1,224 kilometres of the Baltic Sea, environmental organisations – including the World Wide Fund for Nature – have raised serious concerns regarding the project's potential to damage or displace complex ecosystems and delicate marine habitats.

While these environmental concerns are something we can't ignore in the long term, there is no denying the fact that the Nord Stream is one of the most impressive engineering feats ever undertaken. On both small and large scales the project is centred around cutting-edge technology, such as an undersea station capable of housing 24 divers, advanced logistical systems like pipe-laying barges up to four times the length of a football pitch and supersmart electronics able to operate machines and vehicles hundreds of metres beneath the sea.

Dive in and take a closer look at the Nord Stream twin pipeline system to find out not only how it was put together, but also – regardless of its non-renewable crutch – how it demonstrates just how science and technology can help improve the lives of millions and power future development.

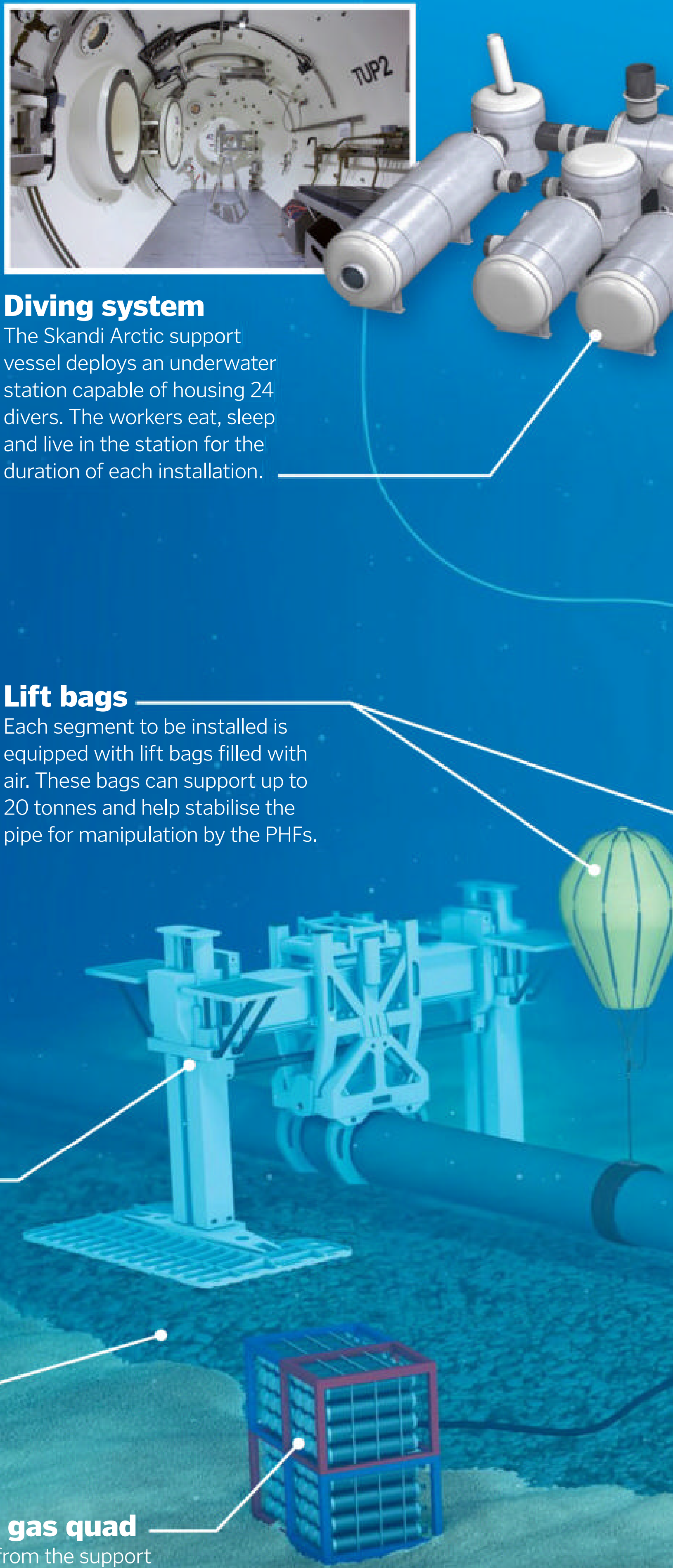
The smartest PIGs on the planet?

The Nord Stream has its integrity checked regularly by pipeline inspection gauges (PIGs). PIGs are like intelligent drain cleaners, being inserted into the pipes before proceeding to automatically detect the smallest changes in the pipeline's structure – due to corrosion, for example – and recording that for later analysis at a control station. PIGs are also able to register any possible movements that the pipeline may have made since installation, such as those generated by small impacts. Each PIG is inserted into the Nord Stream pipeline via a launcher based in Russia before being fired through the system and extracted in Germany. If any issues are detected, a maintenance and repair team is dispatched to investigate.



Pipe laying in action

Learn about the machines, tools, techniques and processes that go into laying undersea pipe networks



Diving system
The Skandi Arctic support vessel deploys an underwater station capable of housing 24 divers. The workers eat, sleep and live in the station for the duration of each installation.

Lift bags
Each segment to be installed is equipped with lift bags filled with air. These bags can support up to 20 tonnes and help stabilise the pipe for manipulation by the PHFs.

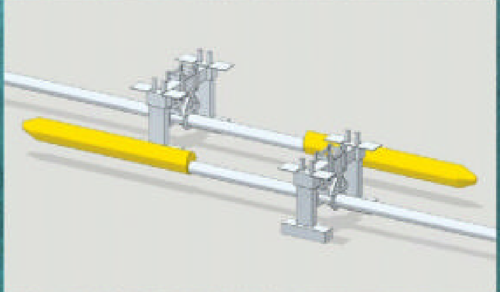
Pipe-handling frame (PHF)
The pipe-handling frames are responsible for positioning the pipes in the correct place for joining together. They can lift up to 150 tonnes and can move the pipes both vertically and horizontally.

Gravel bed
Prior to any pipe segments being delivered, a gravel layer is deposited onto the seabed. This provides a stable foundation for the welding habitat and pipe-handling frames during the installation.

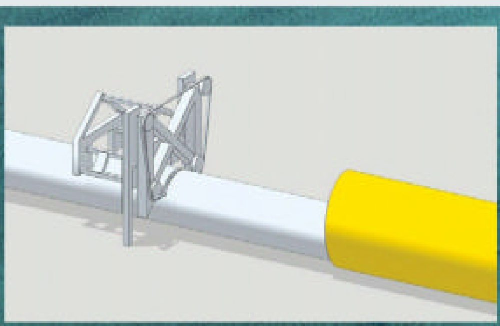
Emergency gas quad
If the gas supply from the support vessel fails, an emergency supply can be gathered from the gas quad, providing the welding habitat with breathable air for up to 72 hours.

Tie-in sequence

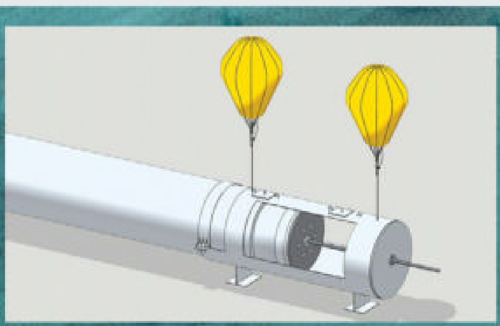
Follow the seven-stage process which is used to join two segments of pipe together



1. Survey
Prior to any human divers arriving at the installation site, a survey is conducted by ROVs to determine everything is in place.

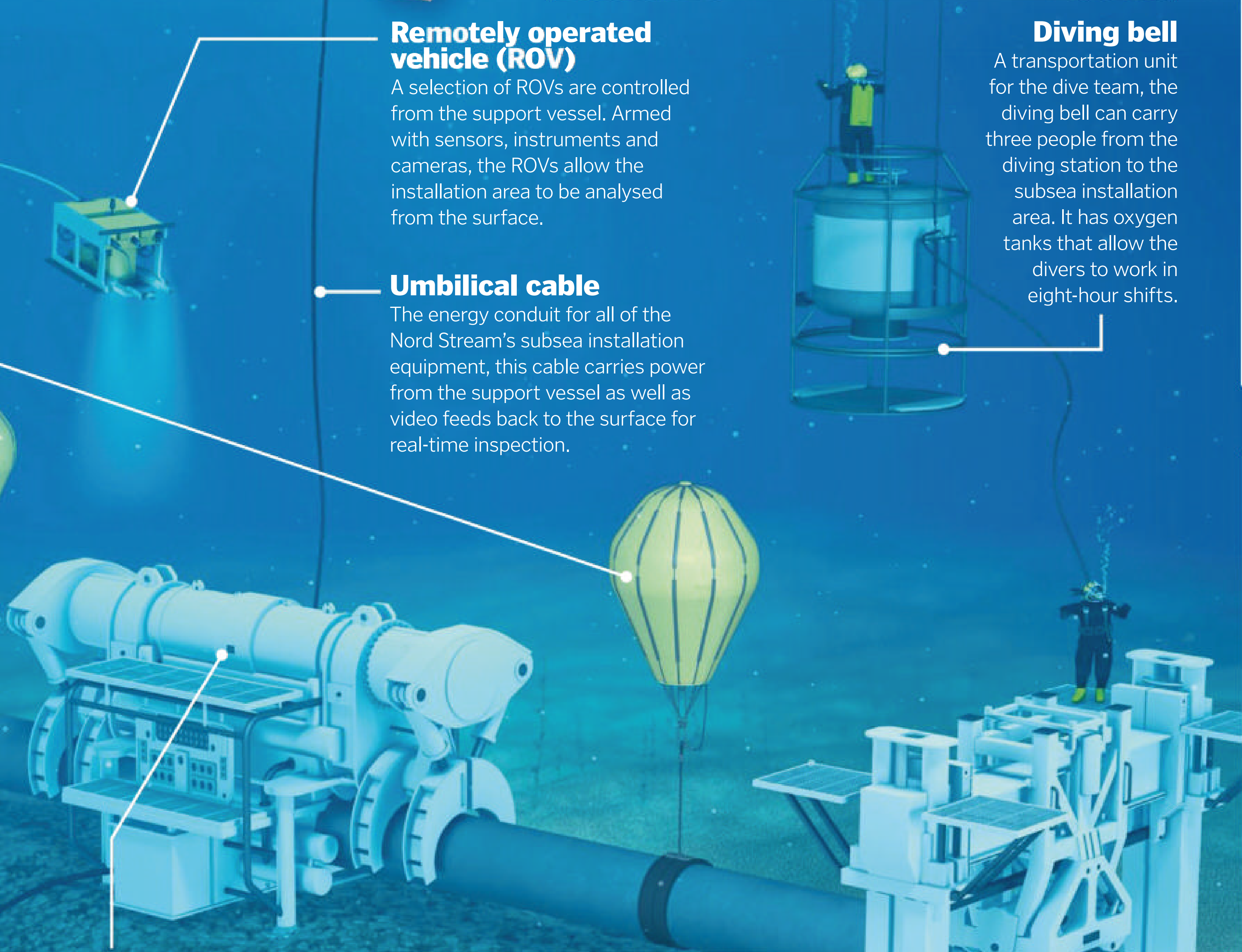


2. Cutting
When in position, the pipe segments may overlap. If so, a diamond wire cutter is used to slice the high-tensile steel.



3. Plugs
Welding plugs are inserted into each end of the segments to hold back the water from the welding area of the habitat.

DID YOU KNOW? *The total construction cost of the Nord Stream 1 was approximately £6.4 billion ($10.1 billion)*



Remotely operated vehicle (ROV)

A selection of ROVs are controlled from the support vessel. Armed with sensors, instruments and cameras, the ROVs allow the installation area to be analysed from the surface.

Diving bell

A transportation unit for the dive team, the diving bell can carry three people from the diving station to the subsea installation area. It has oxygen tanks that allow the divers to work in eight-hour shifts.

Umbilical cable

The energy conduit for all of the Nord Stream's subsea installation equipment, this cable carries power from the support vessel as well as video feeds back to the surface for real-time inspection.

Welding habitat

A dry dock for the dive team as well as an industrial-scale welding machine, the welding habitat is responsible for joining segments of pipe. It is set up in-situ but controlled and powered from the support vessel.

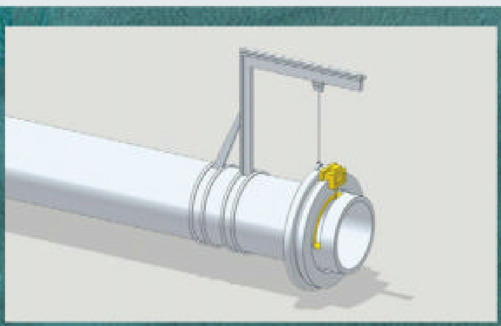
Environmental concerns

Laying millions of tonnes of concrete and steel across the Baltic Sea's seabed was not only an epic logistical challenge, but also an environmental one. The potential to irreversibly damage the seafloor during the laying of a pipeline – especially of this grand scale – can be massive, displacing ecologies of ocean wildlife, injecting huge quantities of silt into the water and destabilising the landscape.

As such, prior to the laying of the pipeline more than 40,000 kilometres of geophysical surveys were conducted, with thousands of regions inspected and catalogued. This allowed the optimal route to be established in order to mitigate damage. In addition, to further safeguard the sea since the installation an environmental monitoring program has been initiated that uses a fleet of specialist vessels – including remotely operated vehicles – to assess the water quality, seabed recovery and local fish, bird and mammal populations.

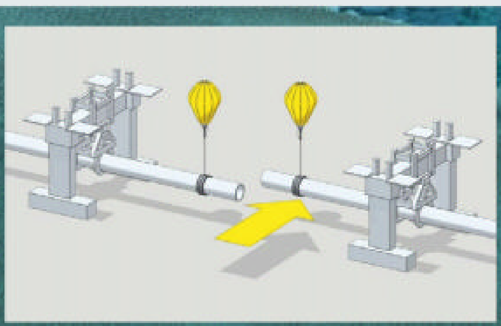
Siberian supply

The gas for the Nord Stream pipeline comes from the Yuzhno-Russkoye oil field in Tyumen Oblast, Russia. The pool of gas lies about a kilometre below the region's surface where there is estimated to be in excess of 1 trillion cubic metres of natural gas – one of the largest deposits in Russia – with an additional 5.7 million tonnes of proven oil reserves. Currently there are more than 140 gas wells in operation at Yuzhno-Russkoye, extracting more than 70 million cubic metres of natural gas per day, the majority now flowing the roughly 2,415-kilometre distance to Vyborg.



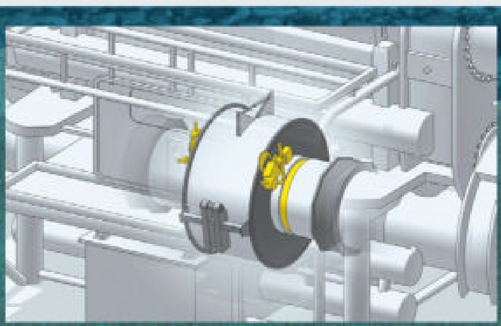
4. Bevelling

A bevelling machine gives both pipe ends a smooth finish. Their surfaces are measured to ensure they are uniform.



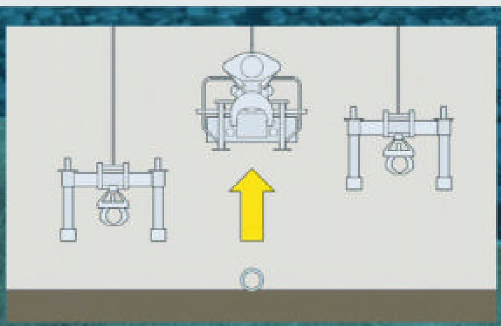
5. Lift

Three pipe-handling frames are used to lift and shift the pipe segments into position – vertically or horizontally.



6. Weld

The segments are then welded together in the welding habitat. Post-weld, the join is inspected using ultrasonic tests.



7. Retraction

Once the welded area has been signed off, the welding habitat is removed, shortly followed by the PHFs.

© Nord Stream AG; Igor Nikolajev P Povarov

How dental drills work

What makes this precision tool perfect for many different dental jobs?

High-speed drills are used for excavating hard enamel, while low-speed devices are better for polishing and finishing enamel

Powered by electric or air-driven motors, modern dental drills have come a long way since the early days of medieval dentistry. As well as a motor, the other main components of today's dental drills are an ergonomic handpiece, gears and a tungsten drill bit, also known as a burr. Located inside the drill's handpiece is a series of drive shafts and gears that transmit rotary motion from the power supply to the tungsten drill bit at the head end.

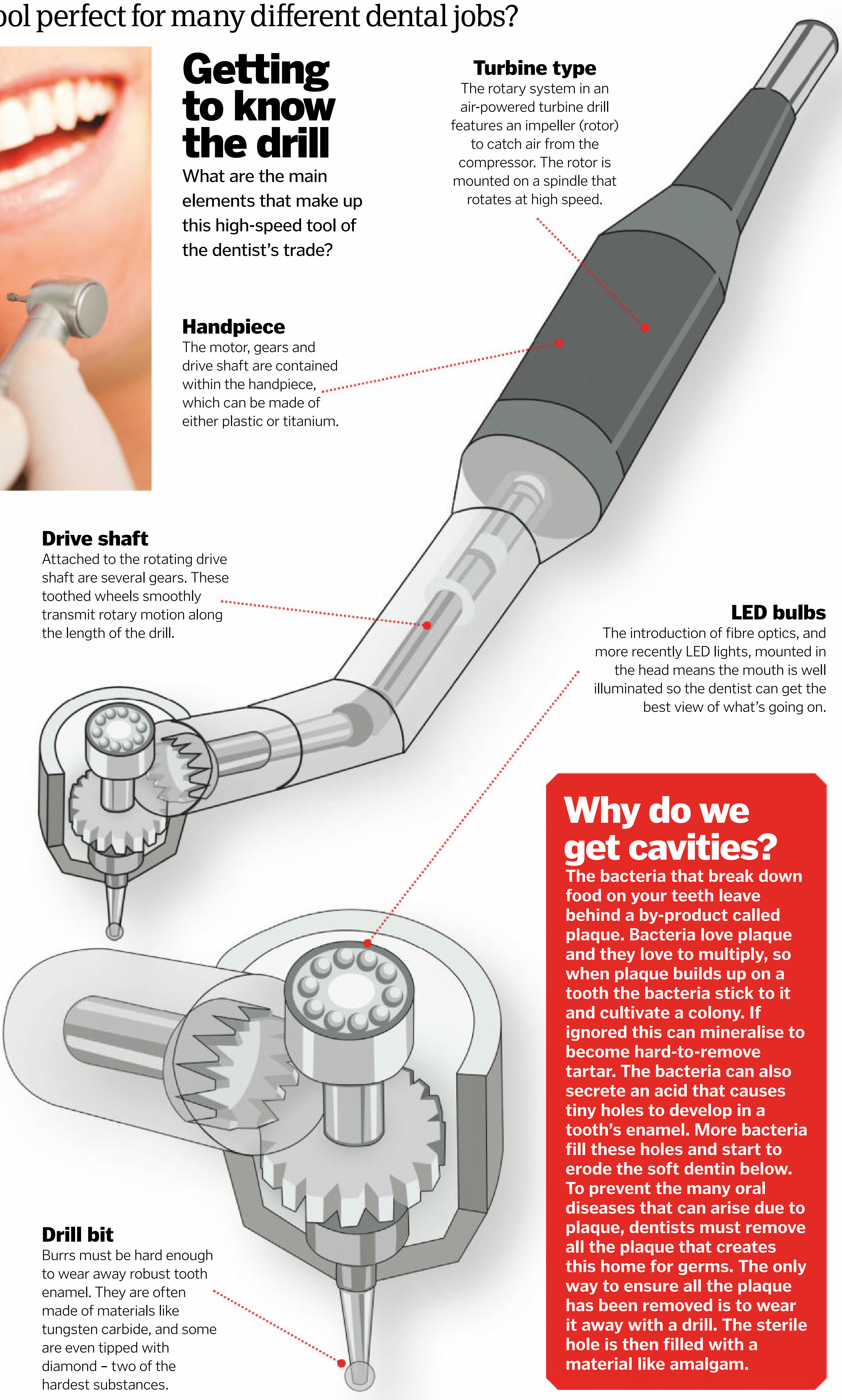
Electrically motorised drills can rotate at about 30,000 rotations per minute. For a turbine-powered drill, a compressor converts pressurised air into mechanical energy that rotates the burr at over 300,000 rotations per minute. This generates a huge amount of heat, so high-speed devices are also connected to a cooling water supply.

New technologies in development – including laser and air-abrasion drills – are hoping to improve the experience of going to the dentist by providing drills that remove decay without generating the heat, noise and vibrations associated with their predecessors. The laser drill achieves this by combining the high-speed pulsed light from a laser with an atomised spray of water droplets to generate hydrokinetic energy. Air-abrasion drills, meanwhile, work like a mini sandblaster, firing a stream of abrasive powder, such as silica or ammonium oxide, at the tooth to blast the decay away.

© Thinkstock

Getting to know the drill

What are the main elements that make up this high-speed tool of the dentist's trade?



Turbine type
The rotary system in an air-powered turbine drill features an impeller (rotor) to catch air from the compressor. The rotor is mounted on a spindle that rotates at high speed.

Handpiece
The motor, gears and drive shaft are contained within the handpiece, which can be made of either plastic or titanium.

Drive shaft
Attached to the rotating drive shaft are several gears. These toothed wheels smoothly transmit rotary motion along the length of the drill.

LED bulbs
The introduction of fibre optics, and more recently LED lights, mounted in the head means the mouth is well illuminated so the dentist can get the best view of what's going on.

Drill bit
Burrs must be hard enough to wear away robust tooth enamel. They are often made of materials like tungsten carbide, and some are even tipped with diamond – two of the hardest substances.

Why do we get cavities?

The bacteria that break down food on your teeth leave behind a by-product called plaque. Bacteria love plaque and they love to multiply, so when plaque builds up on a tooth the bacteria stick to it and cultivate a colony. If ignored this can mineralise to become hard-to-remove tartar. The bacteria can also secrete an acid that causes tiny holes to develop in a tooth's enamel. More bacteria fill these holes and start to erode the soft dentin below. To prevent the many oral diseases that can arise due to plaque, dentists must remove all the plaque that creates this home for germs. The only way to ensure all the plaque has been removed is to wear it away with a drill. The sterile hole is then filled with a material like amalgam.

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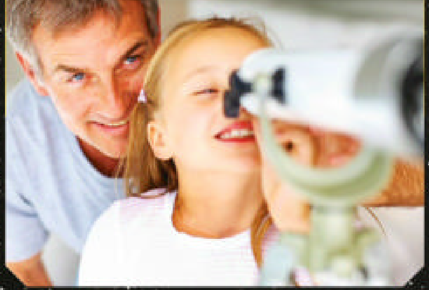

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Inside the battlefield bulldozer

This heavy-duty Caterpillar is built to survive bullet and bomb attacks

Words by **Ailsa Harvey**

The Caterpillar D9 bulldozer is expertly designed for its role in construction work. Taking to farms, building sites and roadsides, their usual passengers drive them in areas of little threat. However, some of the Caterpillars are sent to work in much more turbulent and dangerous places. Working in active war zones, threats to their ability to carry out their engineering tasks are much greater as they are subjected to bullets and explosives. To utilise this powerful machine's tools safely, the Israel Defense Forces (IDF) added extra protection to transform these vehicles into armoured military beasts. Some even say the IDF Caterpillar D9 is indestructible.

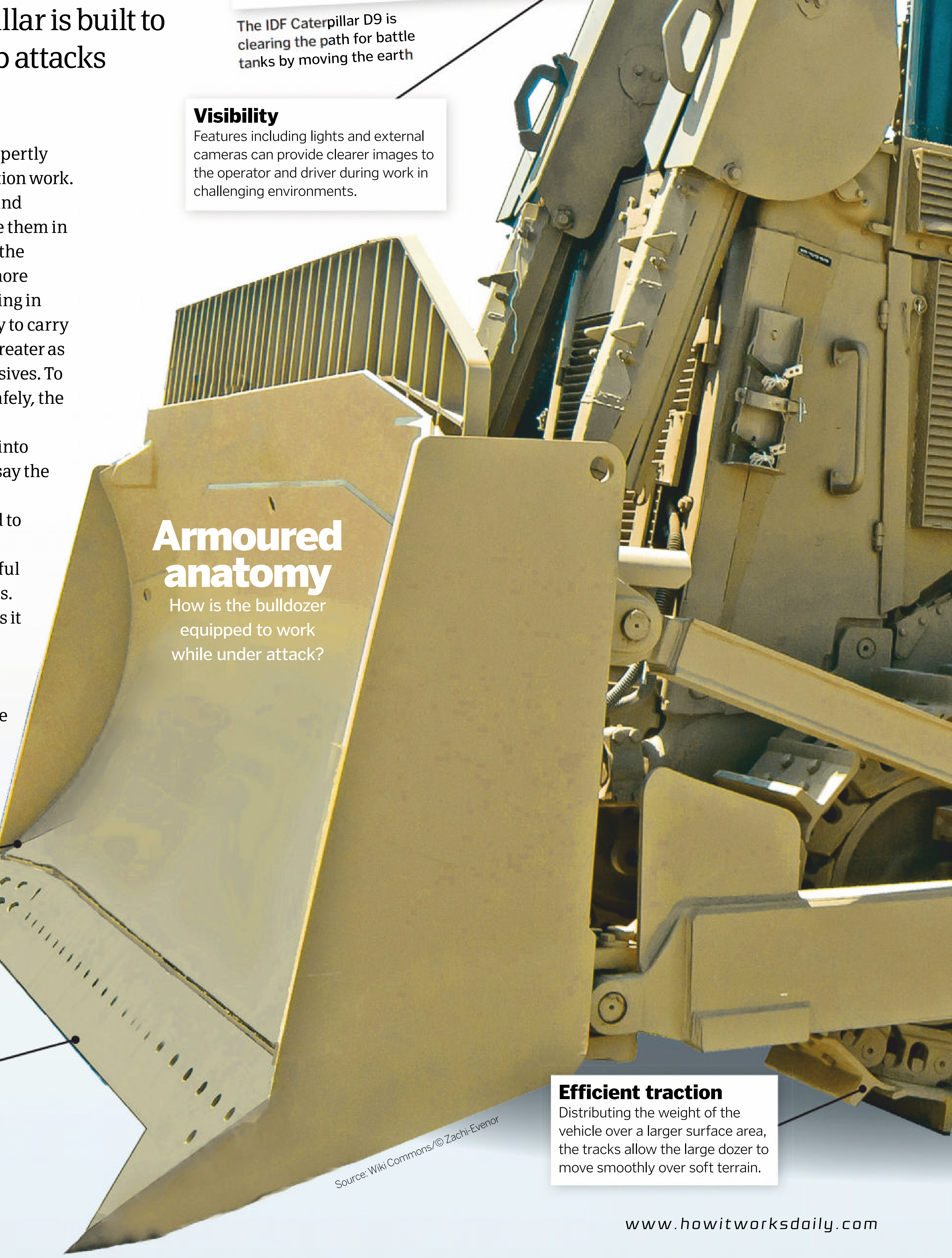
These machines have been deployed to carry out their engineering roles while under attack, and have proved successful during the most challenging operations. The bulldozer's resilient design enables it to dig moats, create sand barriers and even save other vehicles in danger.

Israeli troops have relied on this vehicle since the 1950s. During this time the Caterpillar D9 has picked up a nickname, 'Doobi'. In contrast to its tough defences, this name means 'teddy bear' in Hebrew.

The IDF Caterpillar D9 is clearing the path for battle tanks by moving the earth

Armoured anatomy

How is the bulldozer equipped to work while under attack?



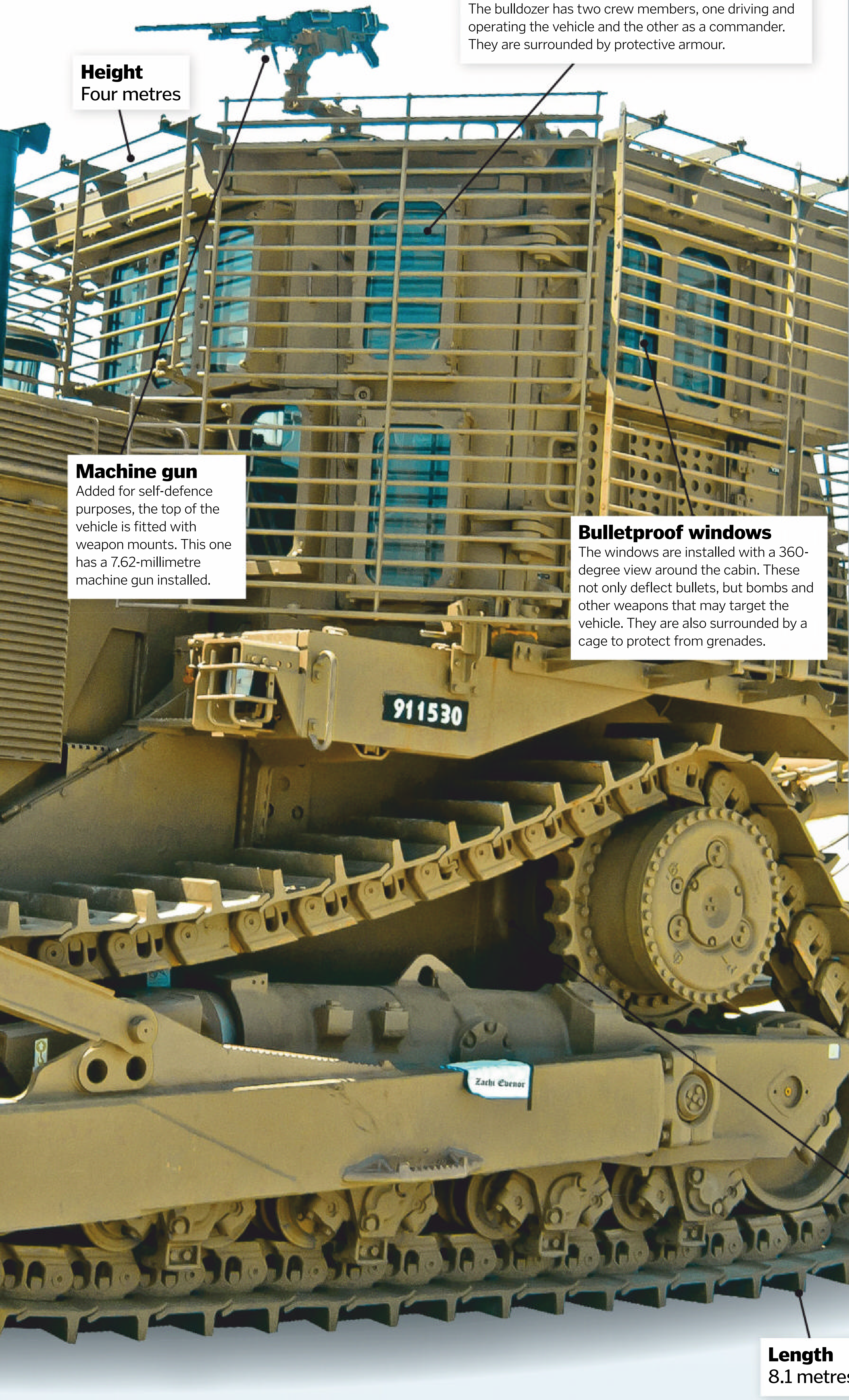
Visibility
Features including lights and external cameras can provide clearer images to the operator and driver during work in challenging environments.

Weight
Over 50 tonnes

Front blade
Controlled by hydraulic arms, this tool can be used to lift soil, dig moats, remove land mines and rescue other damaged vehicles.

Efficient traction
Distributing the weight of the vehicle over a larger surface area, the tracks allow the large dozer to move smoothly over soft terrain.

Source: Wiki Commons/© Zachi-Evenor



Height
Four metres

Operator cabin
The bulldozer has two crew members, one driving and operating the vehicle and the other as a commander. They are surrounded by protective armour.

Machine gun
Added for self-defence purposes, the top of the vehicle is fitted with weapon mounts. This one has a 7.62-millimetre machine gun installed.

Bulletproof windows
The windows are installed with a 360-degree view around the cabin. These not only deflect bullets, but bombs and other weapons that may target the vehicle. They are also surrounded by a cage to protect from grenades.

Rear ripper
A ripper can be attached to the back of the machine and dragged through the earth to loosen rocky terrain.

Engine power
The D9 is powered by the CAT C18 ACERT engine, with a net power over 300 kilowatts.

Length
8.1 metres

Building strength

After the original prototype of the Caterpillar D9 bulldozer was produced in 1954, it wasn't long before its potential for use on the battlefield was explored. Two years later the Israeli army had recruited the vehicle, using the unarmed version during the Sinai War of 1956, the Yom Kippur War of 1973 and Operation Peace for Galilee of 1982.

Exposing the vehicles to these wars provided information to combat engineers about where added armour was required. The bulldozers were modified to account for a range of attacks, from artillery shells and improvised explosive devices to potential chemical attacks. Their widespread military use has caused some controversy among human rights organisations, as their enormous power and unstoppable nature can be used to bulldoze civilian buildings. Meanwhile, military experts say the armour has proved most successful in saving the lives of the D9's operators.

Source: Wiki commons/© mathknight zachi evenor

The cage armour around the cabin shields against rocket-propelled grenades

Inside the world's largest engine

How this huge and powerful diesel engine is winning the race at sea

Words by **Ailsa Harvey**

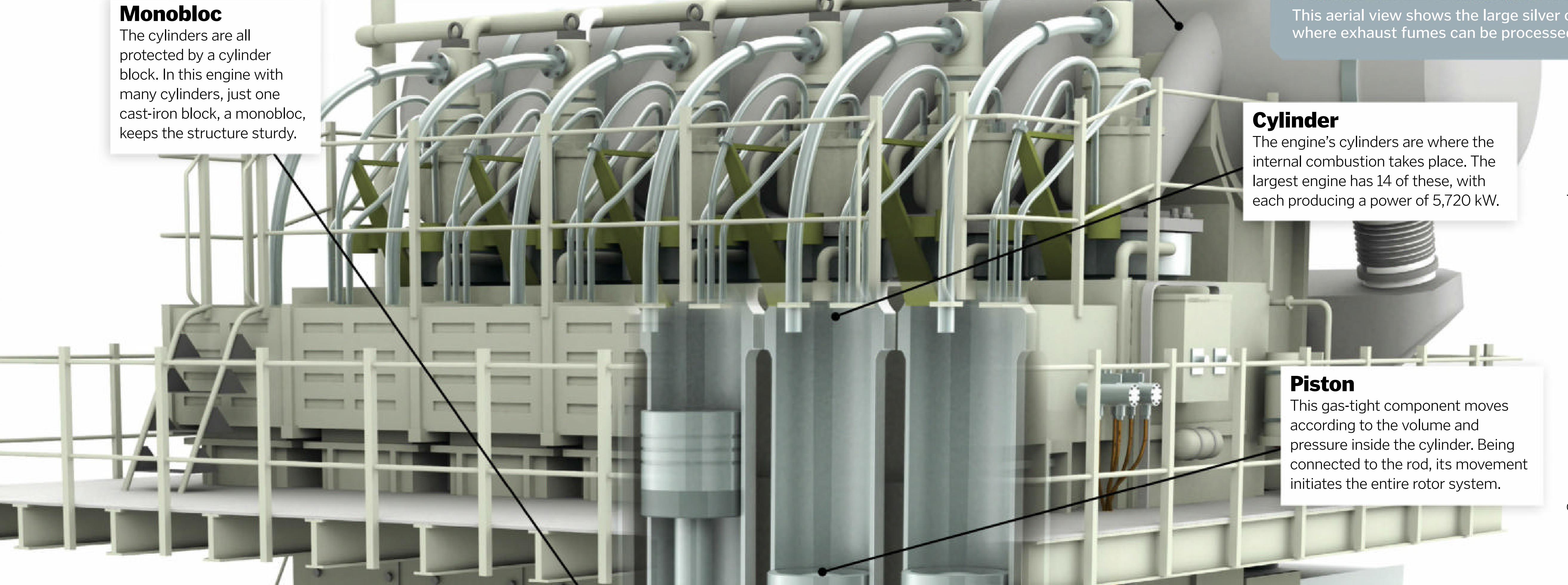
Inside the engine of a car, a line of cylinders works to ignite fuel and provide these vehicles with power. Most cars will have four, six or eight cylinders – some supercars even have 12! Usually the more there are in an engine, the more impressive the power output will be. But no matter how satisfied you are with the power you display as you cruise around the neighbourhood, there is one engine with the ability to make all others feel inferior.

Meet the 14RT-flex96C, a 14-cylinder beast designed to propel the biggest most unwieldy machines in the world.

This engine is suitable for no car, as it stands taller than a four-storey building. It was created by Finnish manufacturer Wärtsilä and first put to use in 2006. It is easy to be taken aback by the sheer size of this engineering feat and to overlook its equally smart design. Faced with the demand for greater power in marine engines, the engineers working on the RT-flex went above and beyond what was originally deemed practical. Previously only 12 cylinders were used on ships. However, this machine takes on two more cylinders while adding extra control, efficiency and longevity to the engine.

Producing power

How does this series of cylinders generate energy?



Exhaust
Exhaust fumes are kept in this chamber to be released or reused. The engine recycles its exhaust for optimum efficiency. Mixing with fresh air, it is reverted back into the engine to be used again. This increases fuel efficiency by 12 per cent.

Fuel injection
Being electronically controlled, the fuel injection valves can be manipulated individually, rather than together. When injected into the cylinder and combined with air, fuel is ready for a controlled explosion.

Monobloc
The cylinders are all protected by a cylinder block. In this engine with many cylinders, just one cast-iron block, a monobloc, keeps the structure sturdy.

Cylinder
The engine's cylinders are where the internal combustion takes place. The largest engine has 14 of these, with each producing a power of 5,720 kW.

Piston
This gas-tight component moves according to the volume and pressure inside the cylinder. Being connected to the rod, its movement initiates the entire rotor system.

Bigger engine, less pollution

Some of the huge numbers surrounding this engine might fill you with concern for the environment, but the engine is in fact extremely efficient for its size, making it one of the least polluting compared to other ship engines.

Equipped with combustion control, heat from the engine that would usually enter the atmosphere as a waste product can be used for other processes on the ship. Additionally, any exhaust gases that are not reused for combustion can be passed through a steam generator. The steam extracted is then used to power electrical generators as it spins turbines. These processes help to reduce the emissions produced by the engine and provide further power beyond propelling the ship.

© Alamy

This aerial view shows the large silver container where exhaust fumes can be processed

107,389 HORSE

Its maximum power is more than 900 times that of an average car

POWER

27 METRES

The same length as three buses

13.5 METRES

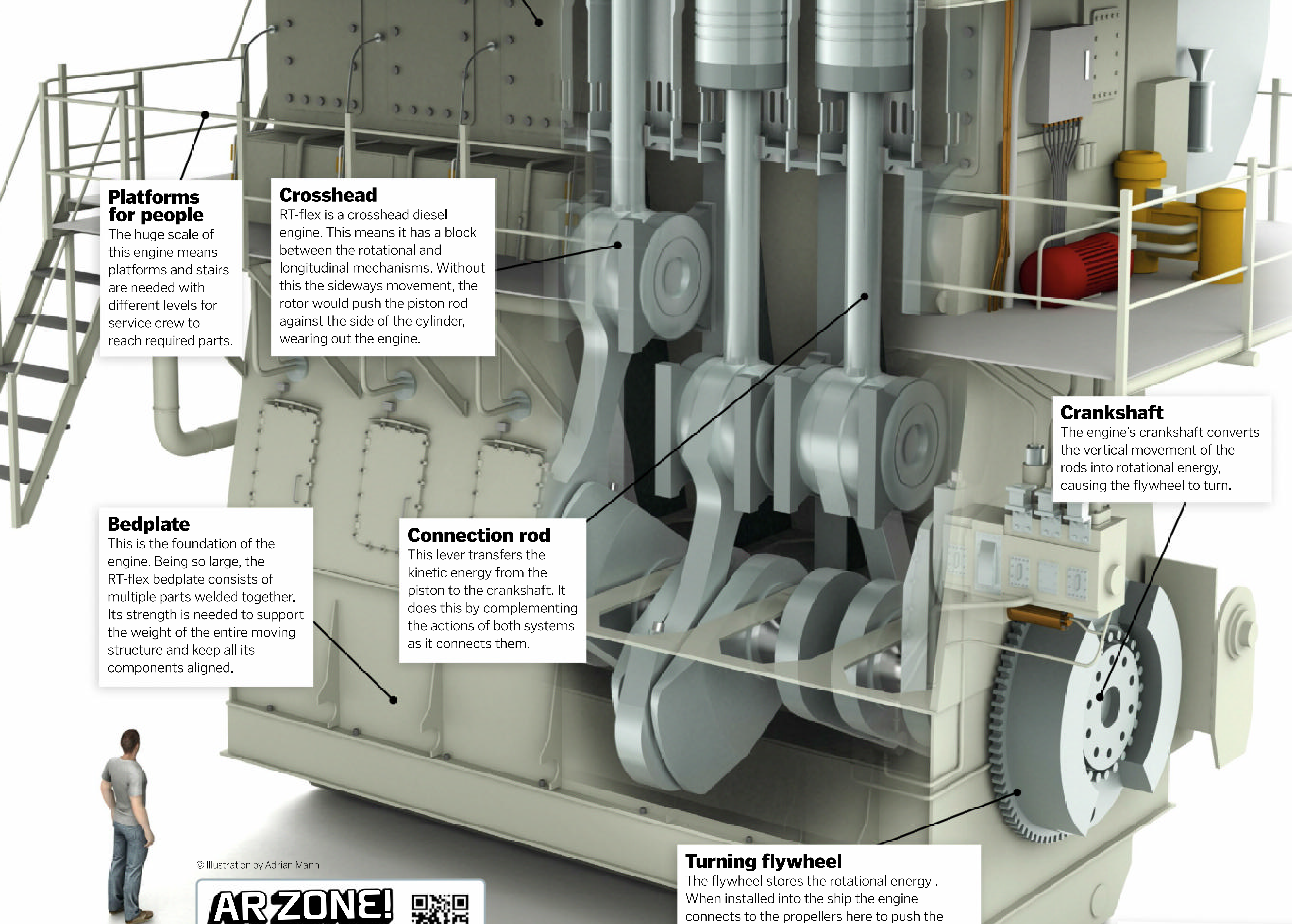
It's twice as tall as an adult giraffe

7,547 LITRES

The fuel consumed in one hour could fill 45 bathtubs

2,000,000KG

Its weight is about the same as 13 houses



Platforms for people
The huge scale of this engine means platforms and stairs are needed with different levels for service crew to reach required parts.

Crosshead
RT-flex is a crosshead diesel engine. This means it has a block between the rotational and longitudinal mechanisms. Without this the sideways movement, the rotor would push the piston rod against the side of the cylinder, wearing out the engine.

Crankshaft
The engine's crankshaft converts the vertical movement of the rods into rotational energy, causing the flywheel to turn.

Bedplate
This is the foundation of the engine. Being so large, the RT-flex bedplate consists of multiple parts welded together. Its strength is needed to support the weight of the entire moving structure and keep all its components aligned.

Connection rod
This lever transfers the kinetic energy from the piston to the crankshaft. It does this by complementing the actions of both systems as it connects them.

Turning flywheel
The flywheel stores the rotational energy . When installed into the ship the engine connects to the propellers here to push the vessel through the water. This rotational energy can turn propellers 102 times a minute.

© Illustration by Adrian Mann

AR ZONE! SCAN HERE

What is the engine used for?

Where can such a colossal engine be found? At present these enormous engines are powering some of the world's largest ships across the ocean at much greater speeds than their rivals. The first ship to be installed with this engine is still in use. Carrying cargo from China to the US, the Emma Mærsk can reach its destination four days earlier than others with smaller and less powerful engines.

Emma Mærsk stretches nearly 400 metres in length, making it one-and-a-half times the length of the Titanic and twice its width. As it carries up to 11,000 shipping containers, each six metres long, it is worthy of housing the largest engine ever made.

Travelling at over 25.5 knots may not seem outrageously fast, but without this engine at the core its competitors only manage around 20 knots. Over long voyages across the sea, that's a lot of time saved.

© Maersk Line

When it was launched, Emma Mærsk was the largest container ship the world had ever seen

Killer crocodiles' deadly anatomy

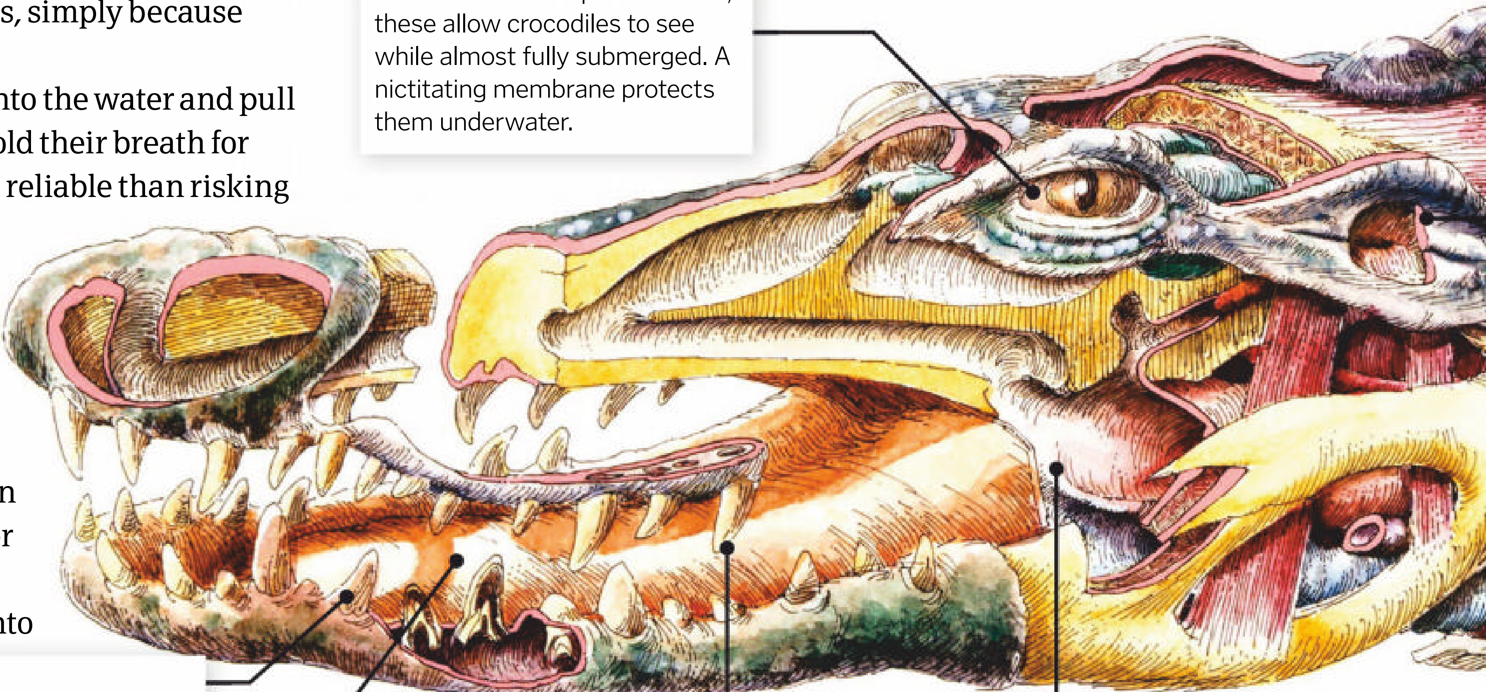
They outlived the dinosaurs, but these hunters are anything but elderly

Crocodiles are often described as living fossils, but despite the fact that their body shape hasn't changed much in the last 200 million years, they are actually some of the most sophisticated reptiles on Earth. Like all living reptiles they are cold-blooded, but that doesn't make them sluggish. Crocodiles have a four-chambered heart and muscles that mimic our diaphragm to ensure they can quickly pump oxygen around their bodies for explosive bursts of speed. Crocodiles are ambush predators; their preferred tactic is to lurk in the river with just their eyes and nostrils visible above the surface and burst out of the water to surprise animals that have come to the bank to drink. If their initial lunge fails, they can chase prey over land at speeds of 17 kilometres per hour. The galloping gait of the crocodile was dismissed as a folk legend for many years, simply because hardly anyone who witnessed it lived to tell the tale.

Once a crocodile has grabbed its prey, it will drag it into the water and pull it under. Crocodiles need air to breathe, but they can hold their breath for around an hour, and drowning prey is easier and more reliable than risking it escaping if they unclamp their mighty jaws. Crocodile teeth are only designed for gripping and puncturing; they have no incisors or carnassials to slice meat off a carcass. Instead they will grip a chunk of flesh with the front teeth and spin violently on their long axis to twist off a bite-sized piece. Crocodiles also don't have lips, so they can't seal their mouth shut when eating. This means they can't swallow food underwater without drowning themselves, meaning each torn-off mouthful has to be brought to the surface and tossed into the back of the mouth.

When food is scarce, their cold-blooded metabolism allows crocodiles to go for as long as two years without eating at all. This, combined with their ability to scavenge rotting meat, was probably what allowed them to survive the event that killed the dinosaurs.

A stealthy croc spies its prey from the water



Eyes
Mounted on the top of the head, these allow crocodiles to see while almost fully submerged. A nictitating membrane protects them underwater.

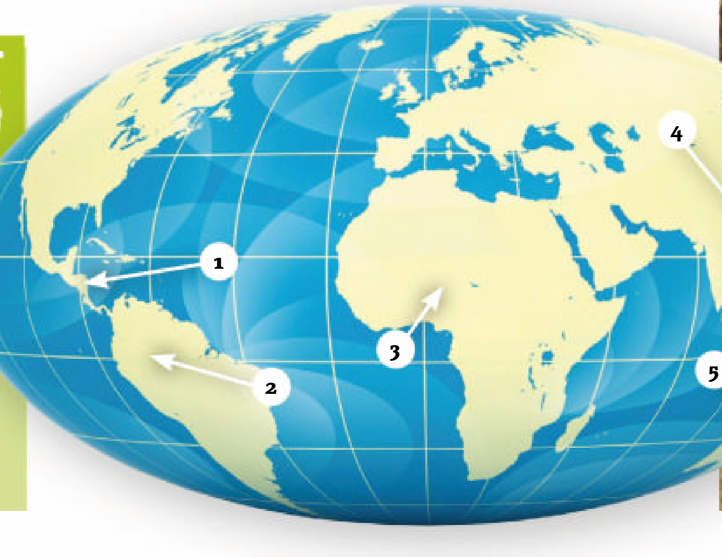
Teeth
Crocodiles have 64 to 70 teeth, which are replaced continuously throughout the animal's life.

Tongue
A crocodile can't stick its tongue out of its mouth because it is anchored to the floor of the mouth all the way along.

Salt glands
Special glands on the top of the tongue allow crocodiles to excrete salt that builds up in their blood in saltwater environments.

Jaw muscle
The massive muscle and its placement a long way forward of the hinge provides a bite pressure almost twice that of a great white shark.

ON THE MAP



Where to find crocodiles

1. Central America
2. The Amazon Rainforest
3. Sub-Saharan Africa
4. Tropical regions of Asia and the Far East
5. Northern Australia

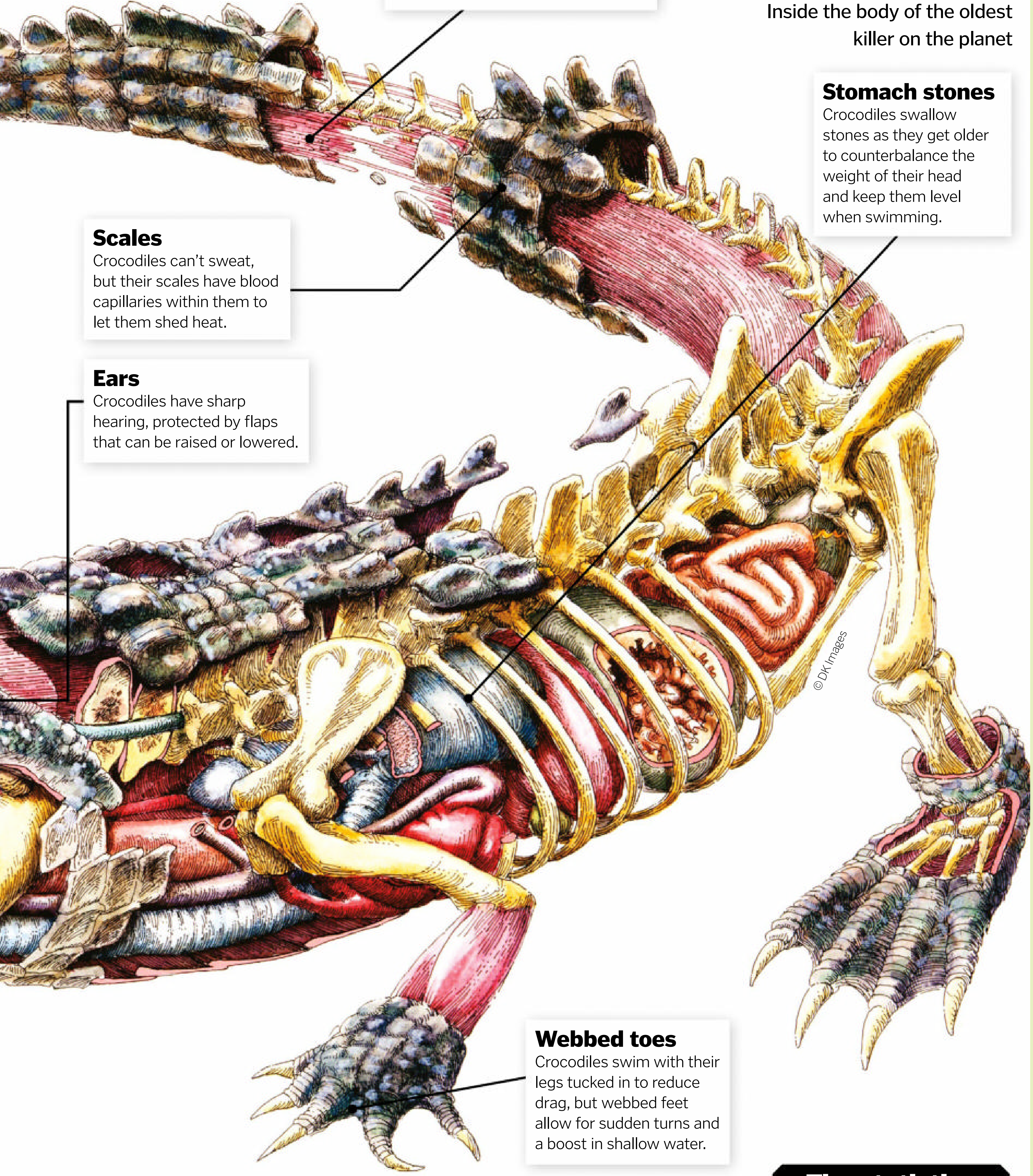
Although the teeth are deadly, it's the death grip that kills

© Adam Jones adamjones.freeservers.com

DID YOU KNOW? *The largest crocodile in the world was called Lolong – he was over six metres long*

Anatomy of a river killer

Inside the body of the oldest killer on the planet



Tail muscle
Saltwater crocodiles can swim at 29 kilometres per hour for short bursts. An Olympic swimmer manages 8.6.

Stomach stones
Crocodiles swallow stones as they get older to counterbalance the weight of their head and keep them level when swimming.

Scales
Crocodiles can't sweat, but their scales have blood capillaries within them to let them shed heat.

Ears
Crocodiles have sharp hearing, protected by flaps that can be raised or lowered.

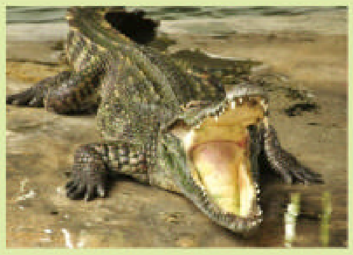
Webbed toes
Crocodiles swim with their legs tucked in to reduce drag, but webbed feet allow for sudden turns and a boost in shallow water.

© DK Images

Please don't try this one at home

© Came october

The statistics



Saltwater Crocodiles

Type: Reptile

Diet: Carnivore

Average life span in the wild: 70 years

Weight: 1,300 kilograms

Size: 6 metres

Crocodile or alligator?

A field-spotter's guide to carnivorous reptiles

Crocodile

Location: Crocodiles live in Africa, Asia, Australia and the Americas in both fresh and salt water.

Snout shape: The V-shaped snout is a general-purpose design for catching fish, reptiles and mammals.

Jaws/teeth: The upper and lower jaws are the same width, so the fourth tooth in the lower jaw sticks up.

Colour: Mottled green or sandy yellow, with slightly darker scales along the back and tail.

Skin: Each scale has a pore near the edge, visible even on crocodile handbags and wallets.

Alligator

Location: Alligators are only found in the southern United States and China and vastly prefer freshwater.

Snout shape: A heavier, U-shaped snout provides extra strength for cracking turtle shells.

Jaws/teeth: A wider upper jaw completely covers all the teeth in the lower jaw when the mouth is closed.

Colour: Much darker, sometimes almost completely black depending on the water quality.

Skin: Alligators only have pores on the scales that cover the upper and lower jaws.

Other
A crocodile with a very long, thin snout is actually a gharial. Caimans look like a slightly smaller alligator, but you can tell them apart because the large scales on their head form a four-four-two pattern, instead of two-two-two.

How do penguins swim?

Revealing the secrets of the penguin's underwater prowess

Penguins are streamlined for diving into the icy sea

Flippers are key to a penguin's swimming abilities

Though ungainly on land, the flightless penguin has physical characteristics perfect for swimming through water – some species are known to be at sea for up to 75 per cent of their lives. Spending so much time in the water puts penguins at risk from predators, so swimming skills are essential. While their long, streamlined bodies and short legs give them a clumsy gait when waddling on land, penguins' wings have a unique characteristic that gives them surprising agility in water.

While these wings are not suitable for aerial flight – unlike the delicate lightweight bones of other birds, penguin bones are solid – they are perfect for soaring through water, with the gentoo penguin reaching speeds of up to 35 kilometres per hour. Referred to as flippers, the penguin's stiff wings act as the perfect natural paddle. What's most interesting, however, is that as well as being able to flap their flippers up and down like wings, penguins can also twist them in a corkscrewing motion.

The joint attaching the flipper to the body is similar to that of a human shoulder, enabling the bird to better control its movements and speed. A swimming penguin can rotate one flipper in one direction and the other in another, enabling it to turn instantly or stop suddenly. Twisting causes a greater surface area of the wing to move over the water, generating a greater thrusting force so the penguin can increase its speed without the need for more flapping.

Another technique the penguin uses for moving through water is porpoising. Whenever it needs to breathe, the penguin will periodically swim fast under the water and then use its flippers to leap from the water in an arc. The momentum of porpoising helps penguins when they need to flee quickly from predators.

The humble penguin is one of the planet's best-equipped swimmers, and the 'twisting flipper' motion has been applied by scientists who have developed robot technology that helps to improve the efficiency and performance of underwater vehicles.

Penguins in motion

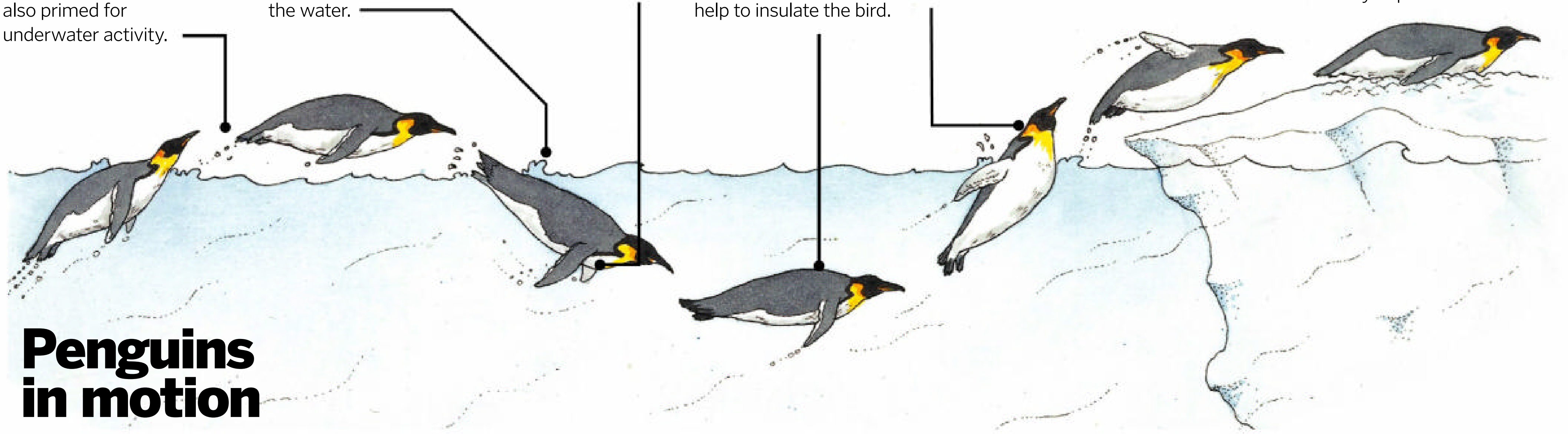
1 Propel like a penguin
It's not just the flippers that make the penguin such an able swimmer. The rest of its anatomy is also primed for underwater activity.

2 Body
A long fusiform – or torpedo-shaped – body helps the penguin glide gracefully through the water.

3 Flippers
The stiff yet flexible flippers are shorter than the wings of other birds, making them powerful oars.

4 Feathers
Short, broad feathers help to keep water away from the penguin's skin and tufts of down on the base of the feather help to insulate the bird.

5 Colouring
A penguin's striking colouration is essential in helping to keep it safe from predators in the water. If a killer whale looks up, it will not see the penguin because the light ventral underside blends in with the light from above. A predator looking down on a penguin, meanwhile, shouldn't spot the creature because the dark dorsal side blends in with the murky depths below.



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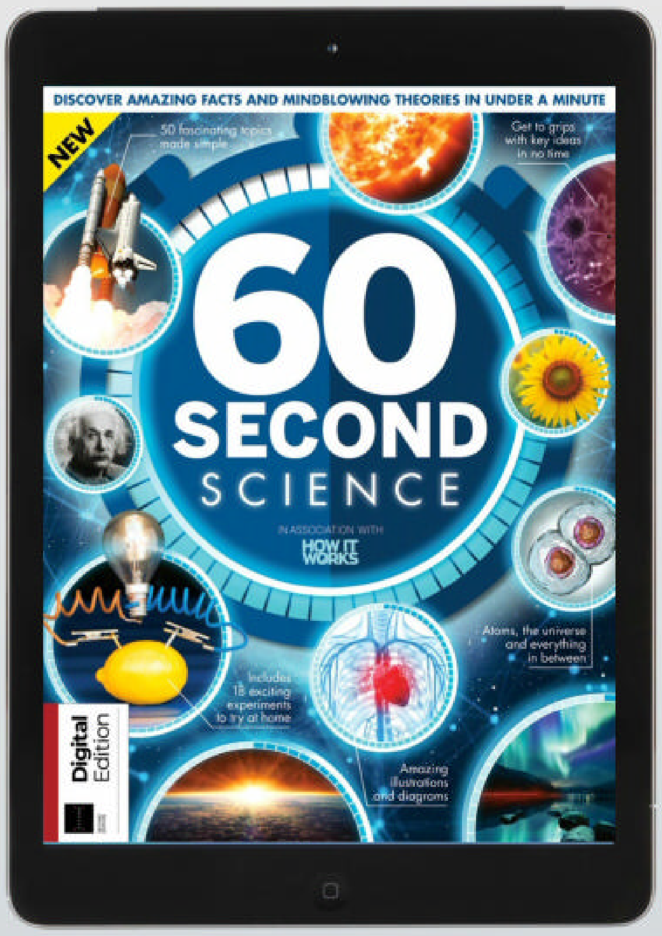
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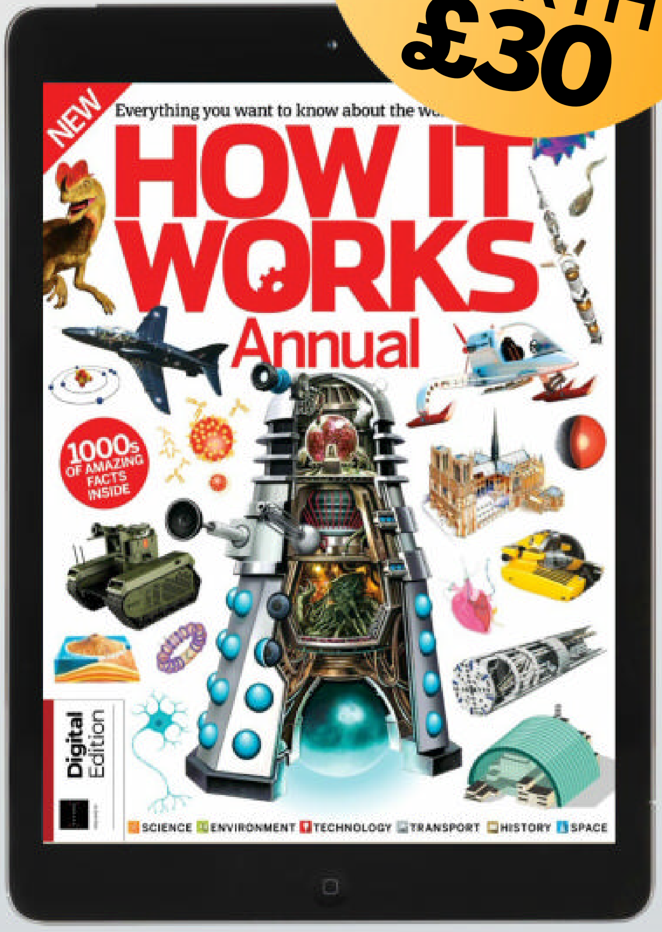
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BRAIN DUMP

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© Getty

Why do some species exist for millions of years and others a lot less?

Georgia Kennedy

■ A species' survival depends on both its ability to adapt and its environment. Living things are continuously undergoing subtle changes to better suit the environment around them. During periods of particularly rapid climate change, the introduction of new diseases or the addition of new predators, some species cannot adapt quickly enough to survive. A genetically diverse species is more likely to survive, while those subjected to less change may survive for longer. **AH**

DID YOU KNOW?

99.9 per cent of Earth's species that ever existed are extinct

How do they make the Playstation 5's graphics look so lifelike? Why didn't they make PS4 or PS3 games look as good as in the recent demo?

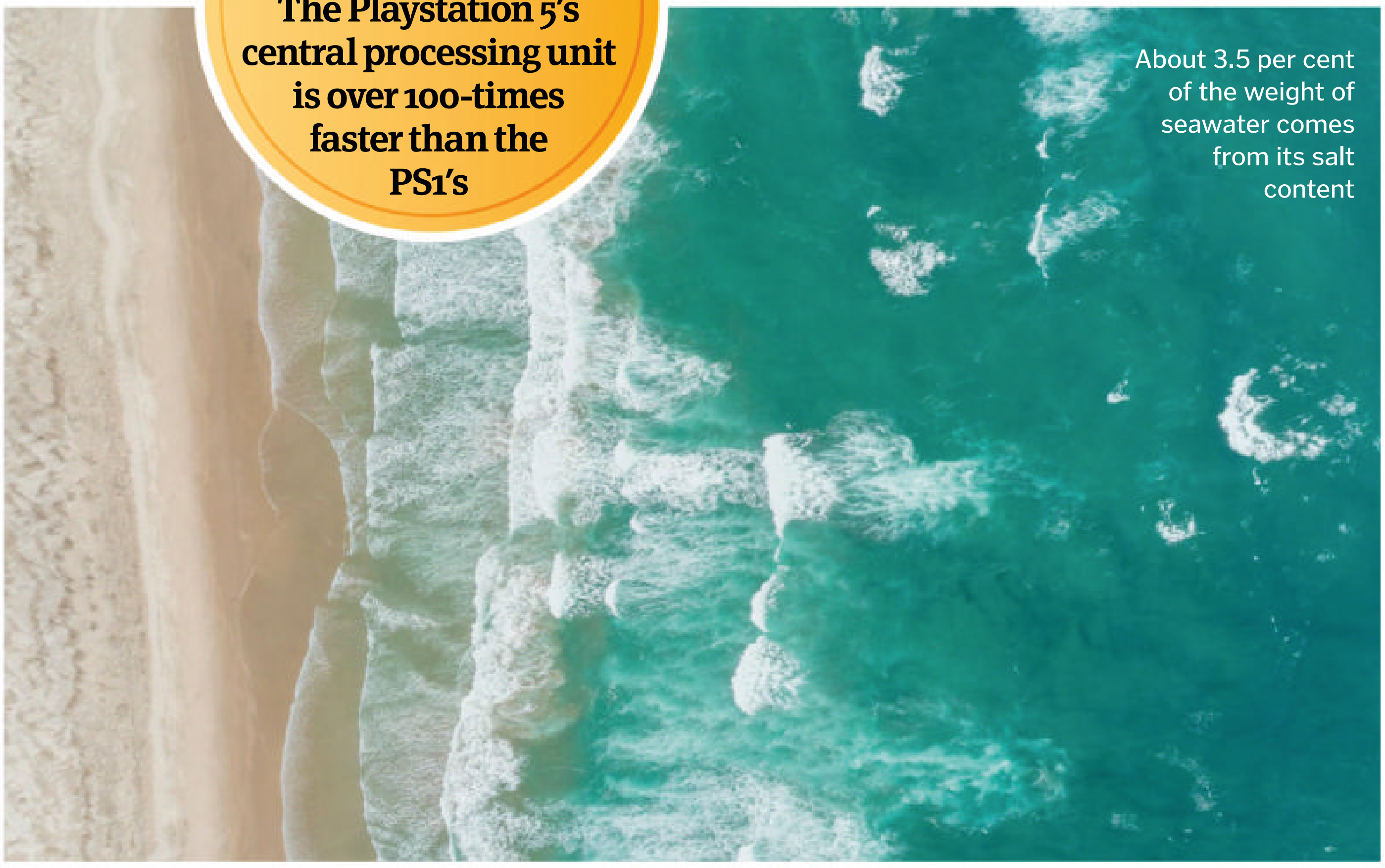
© Epic Games

Rahim Mirza

■ Photorealistic graphics have been a dream of most gamers for decades, but the powerful hardware required is only now starting to become available. According to the CEO of Epic Games, Tim Sweeney, a truly photorealistic game would require 40 teraflops of computing power. The PS4 'only' has 1.84 teraflops of power, and even the most powerful and expensive gaming PCs today struggle to achieve 30 teraflops. **BB**

DID YOU KNOW?

The Playstation 5's central processing unit is over 100-times faster than the PS1's



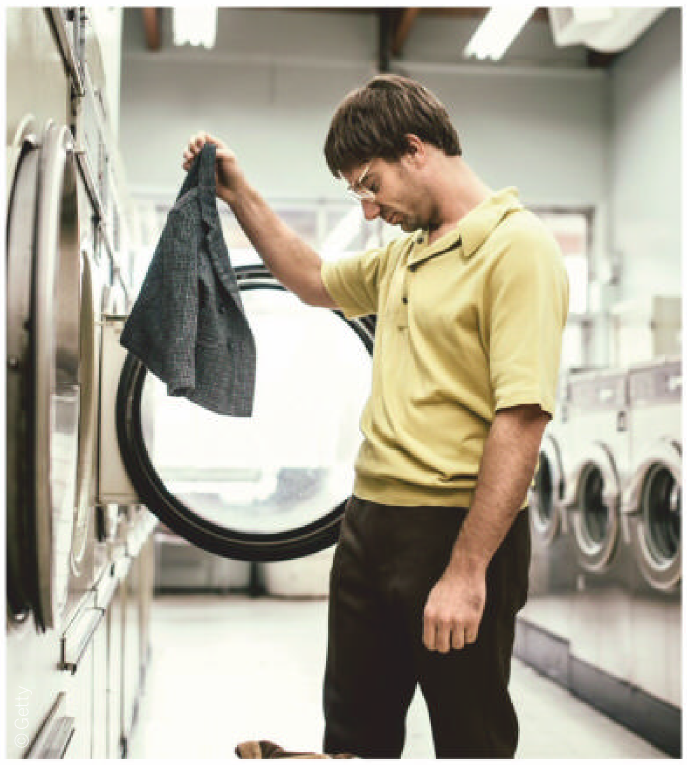
About 3.5 per cent of the weight of seawater comes from its salt content

© Getty

Why is the sea salty?

Eva Magyaricsova

■ Because of the carbon dioxide in the atmosphere, rain is slightly acidic. When rain falls on land, this acidity erodes rocks, releasing mineral ions that are carried into rivers and then the sea. Some of these are sodium and chloride, which together make salt. It's estimated that 4 billion tonnes of dissolved salt is delivered to the ocean by the water cycle each year. Vents in the seafloor and underwater volcanic eruptions are another source of salinity, releasing these ions from rocks beneath the seabed. **NR**



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Why do clothes shrink in the wash?

Cally Milne

■ When exposed to the hot water within a washing machine, long chains of molecules called polymers that make up clothing fibres such as cotton are broken and relax, returning to their smaller size after being stretched during the creation of the fabric. **SD**

© Getty

Unlike fossil fuels, wind turbines do not produce carbon dioxide

What is global warming and how can we stop it?

Isabel Daniells

■ By using and wasting less water, food – especially meat – and electricity and limiting our transport use, we minimise our personal carbon footprint and help to reduce global warming. Global warming describes Earth's rise in temperature due to the increasing volume of greenhouse gases trapping heat in the atmosphere. To reduce gas emissions, we can adapt our way of living. Renewable energy can power our homes using natural elements like solar power rather than the burning of fossil fuels. **AH**

BRAIN DUMP

A tesseract is a 4D shape, with every face being a cube

© Getty

If we had a third eye, would we be able to see in 4D?

Adam Albu

▪ While losing an eye loses a dimension, or depth, adding an eye doesn't add an extra fourth dimension.

What we see is created by the brain using a 2D image from the eyes. A third eye might further assist our perception of depth, but the brain would still interpret the image as 3D. Humans are able to see in three dimensions: length, width and depth. Physicists have theorised a fourth dimension – time – but living in a 3D world, our brains wouldn't know how to process or understand further dimensions. **AH**

DID YOU KNOW?

The ocean contains about 97 per cent of Earth's water, with an average depth of 3,682 metres

What would happen if you poured petrol in a diesel car, or vice versa?

Joe Melling

▪ It would certainly damage both engines if you tried to run them for any length of time, though the petrol engine would probably break down first. While both types have to ignite their fuel first to run, petrol engines do this with an electric spark and suck the fuel through with carburettors, while diesel engines inject the fuel directly into the cylinder and ignite the fuel by compressing it. Diesel has a lower auto ignition temperature than petrol, so while petrol won't ignite in a compression ignition engine and will cause the vehicle to stall, diesel in a spark ignition engine ignites too easily and burns with more power than a petrol engine is designed for, damaging it. **BB**

Make sure you choose the right fuel at the garage, or the consequences for your engine could be disastrous

© Getty

© NASA/Event Horizon Telescope

How big can black holes get?

Miguel Sanchez

▪ A black hole's growth starts to slow at around 10 billion solar masses – one solar mass being the weight of our Sun. Black holes have a theoretical upper limit of 50 billion solar masses, at which point gas in the accretion disc – the halo formed by matter being sucked in by the black hole – surrounding the ultramassive object would begin to form stars. **NR**

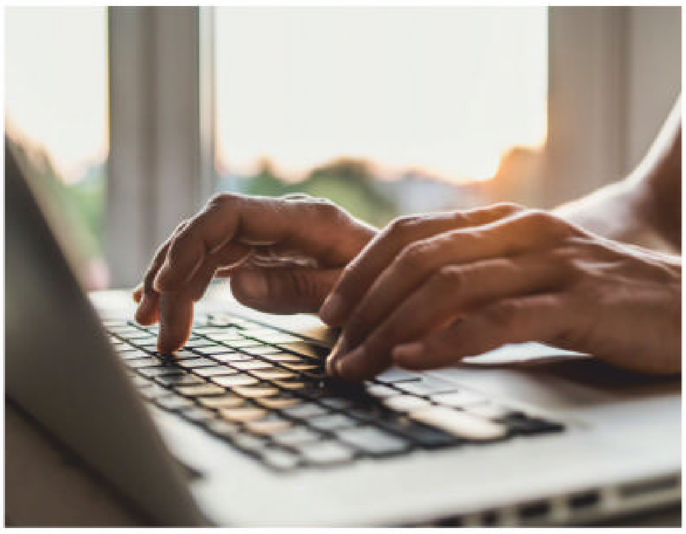
A standard candle flame can reach temperatures of around 1,300 Kelvin

© Getty

Does fire have a weight?

Levi Nonya

▪ Yes, fire does indeed have a weight. However, it's relative to its density. As a plasma – essentially hot air – a fire has around one-quarter of the density of normal air, with the average flame weighing around 0.3 kilograms per cubic metre, or 0.3 grams per litre. Because the density of a flame is lower than air, much like a bubble underwater, it rises, which is why flames flow upwards in air. **SD**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We type quicker and with more accuracy on a familiar keyboard

How can my fingers find keys on the computer keyboard so quickly?

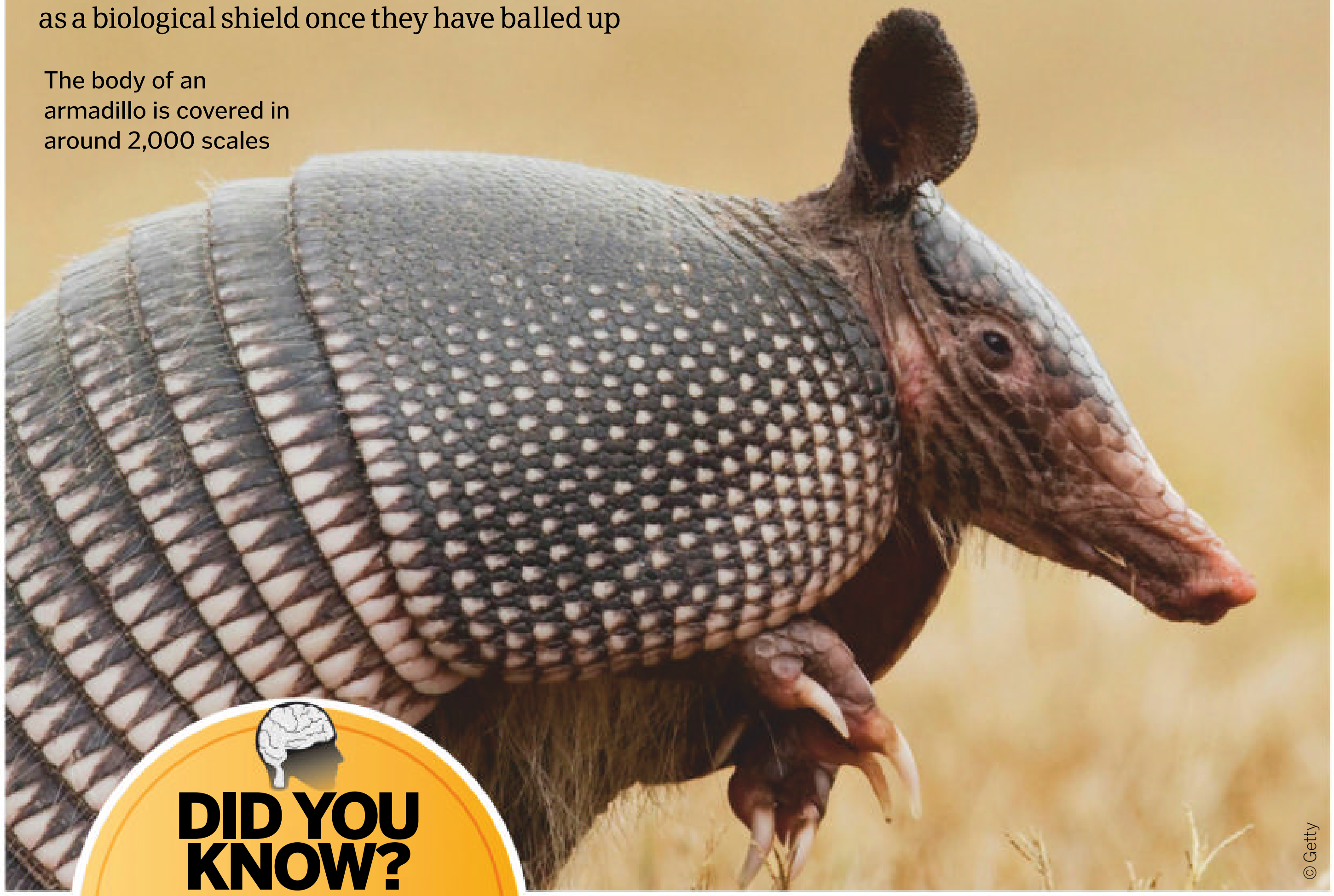
Stefan Cobb

■ The more we type on a keyboard, the more ‘muscle memory’ we build up, allowing our fingers to find the correct keys as if on autopilot. Practice will also allow you to find the keys quicker while making fewer errors. Using a keyboard you are familiar with will be easier, as you are used to the spacing and size of the keys – you’re likely to make more mistakes using a different keyboard! **NR**

What are armadillo scales made from and why have they evolved them?

Caroline Ward

■ The scales – or scutes – that cover the majority of an armadillo’s body are made from the same material that makes up fingernails – keratin. This hard and durable material is a great line of defence against predators, acting as a biological shield once they have balled up to protect vulnerable areas of their body not equipped with a keratin coating. Much like the scales of pangolins or the spines of porcupines, armadillos evolved this natural shield as a defence mechanism against predators around 50 million years ago. **SD**


The body of an armadillo is covered in around 2,000 scales

© Getty

DID YOU KNOW?

The giant armadillo (found in parts of South America) can have up to 100 teeth

Glass-blowing requires molten glass to cool just enough to shape it

© Getty

If I went to the beach and heated up the sand, would I be able to make glass?

Jeff Jacobs

■ Absolutely you could. Most of the sand on a beach is made of silicon dioxide, and when this is melted it turns into a liquid. When this liquid cools it doesn’t turn back into sand, but glass, which is a cross between a liquid and solid that chemists call an amorphous solid. However, you’d need a temperature far beyond a hot beach bonfire burning at 1,100 degrees Celsius to melt sand, which turns liquid at 1,700 degrees Celsius. **BB**

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BOOK REVIEWS

The latest releases for curious minds

Endangered Animals: And How You Can Help

Good habits for the younger generation

- Author: **Sam Hutchinson**
- Publisher: **Princeton Architectural Press**
- Price: **£14.22 / $17.95**
- Release: **25 August**

We're starting to see many more significant examples of the human impact on climate and the environment than our parents and grandparents ever did. And it's our children and grandchildren who will inherit a planet whose plant and animal species are gradually being pushed over the brink of extinction. Younger generations are increasingly aware of the precarious balance of life on Earth, and it's these children that this book it aimed at.

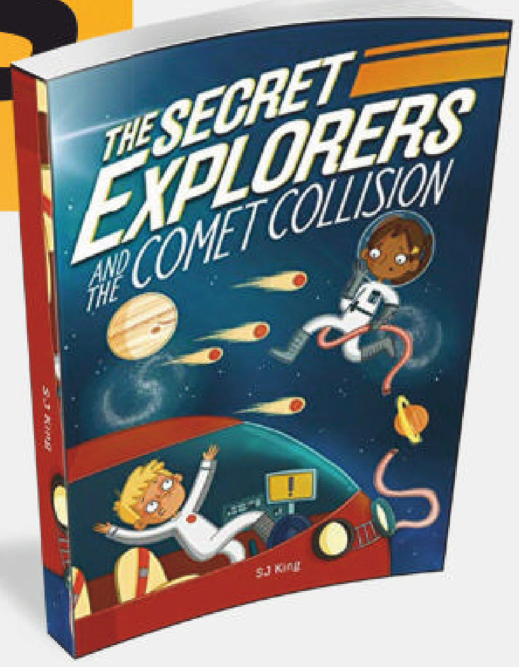
Endangered Animals: And How You Can Help has a very clear message, cover to cover. It takes the reader through seven different environment types – ocean, desert, polar, rainforest, savannah, forests and mountains – providing a short description of the environment and listing the kind of animals that are found there – or those that were found there until hunting, pollution, climate change, deforestation or other forms of human interaction consigned the species to history. The introduction describes the International Union for Conservation of Nature (ICUN) 'red list' used as a scientific gauge of the level of threat a species is subjected to (plus an eighth level, 'extinct') and each species listed in the book is graded accordingly, detailing the reason for their decline.

Hutchinson's text is clear and should be simple for a primary school pupil to understand. It's accompanied by Sarah Dennis' distinctive woodblock-style illustrations in primary colours, with environmental scenes for younger pupils to search and find each animal. As a final thought, a 'You Can Help' page empowers readers to adopt small-but-effective environmentally friendly habits such as turning off electronic devices, walking and cycling or buying products that use recycled or recyclable packaging.

It's a good educational tool, encouraging older readers to be more aware of the delicate natural balance that human expansion is upsetting. In its hardback form it will make an attractive library book for young school children to pore over and to identify animals.

★★★☆☆

Endangered Animals has a very clear message



The Secret Explorers and the Comet Collision

The team are reunited for another mission

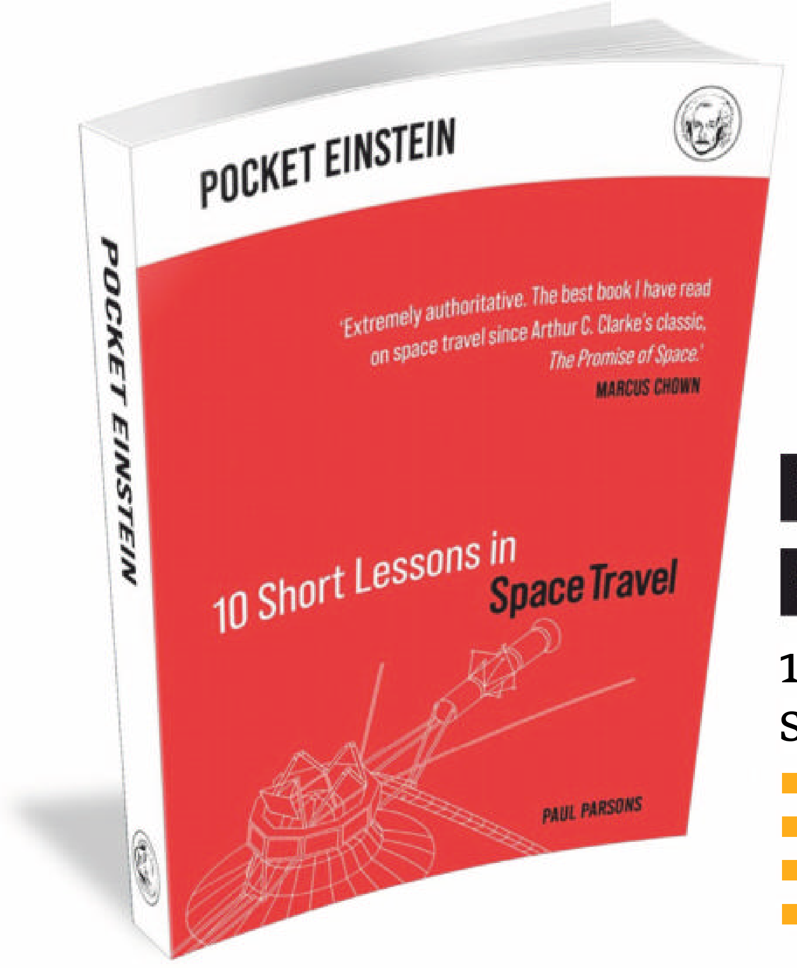
- Author: **S.J. King**
- Publisher: **DK Children**
- Price: **£5.99 / $5.99**
- Release: **Out now**

The Secret Explorers have been called into action, and this time it's a space mission. Roshni, the group's space explorer, and Ollie the rainforest explorer are needed for a trip to the Milky Way. But when will Ollie's rainforest knowledge come into play?

As they navigate in an atmosphere unlike their own, Ollie learns all about the importance of gravity on Earth, while Roshni acts as the teacher, sharing her passion for outer space with her companion and you, the reader. Amid the fictional drama of asteroid dodging, dangerous plot twists and space probe searching you will find yourself absorbed in the fascinating wonders of space and facts about the Solar System's largest planet.

Each page displays the unfolding action through beautiful and informative illustrations. These help in understanding the energetic characters and visualising each step of their escapade. This book is a suitable read for any adventurous young reader between the ages of seven and nine. Children are not only taught the facts of science, but the thoughtful narrative can help explain the great importance of perseverance, teamwork and supporting each other.

★★★★☆


POCKET EINSTEIN
'Extremely authoritative. The best book I have read on space travel since Arthur C. Clarke's classic, The Promise of Space.'
MARCUS CHOWN
10 Short Lessons in Space Travel
PAUL PARSONS
POCKET EINSTEIN

Pocket Einstein

10 short lessons in space travel

- Author: **Paul Parsons**
- Publisher: **Micheal O'Mara**
- Price: **£9.99 / $12.74**
- Release: **Out now**

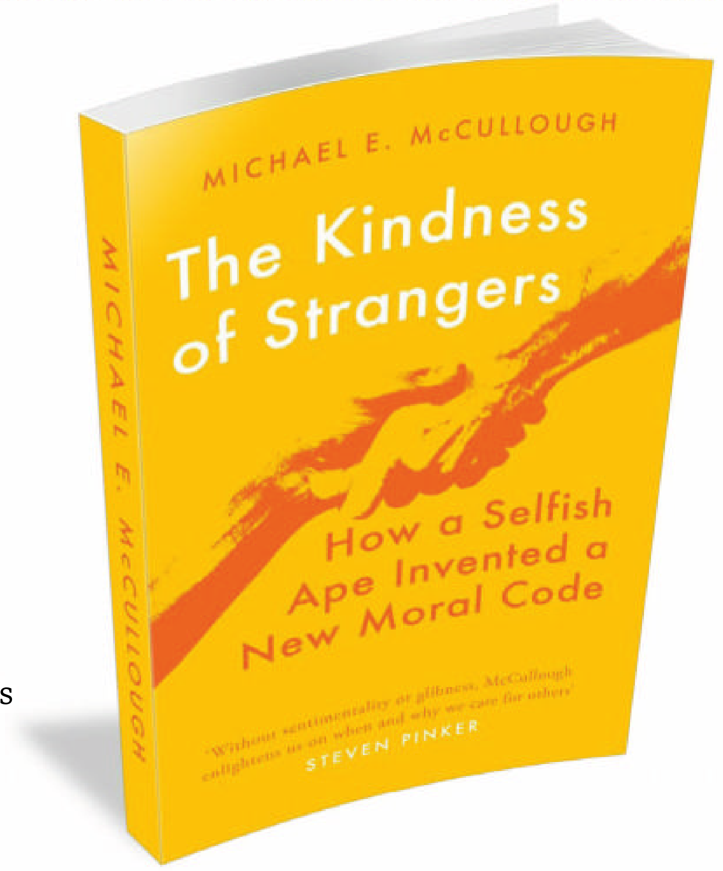
How did humans break through the clouds and journey into open space? And what could the future hold for humankind's cosmic conquests? As part of the Pocket Einstein series, *10 Lessons in Space Travel* answers those questions and more. Trying to condense the history and technological advancements of humankind's exploration of the universe must have been no easy task for author Paul Parsons. Nevertheless he has managed to cram the events that allowed us to reach for the stars into this insightful pocket guide to all things space. If you're looking to learn more about what it takes to leave Earth and what lies beyond, then this bitesize book is for you. In ten short lessons Parsons outlines the origins of space travel, game-changing discoveries, the inventions that let us see deep into space and the future of space tourism. Parson writes as an expert in his field while simultaneously informing and entertaining the reader.

★★★★☆

The Kindness of Strangers

How a selfish ape invented a new moral code

- Author: **Michael E. McCullough**
- Publisher: **Oneworld Publications**
- Price: **£20.00 / $30.00**
- Release: **3 September**

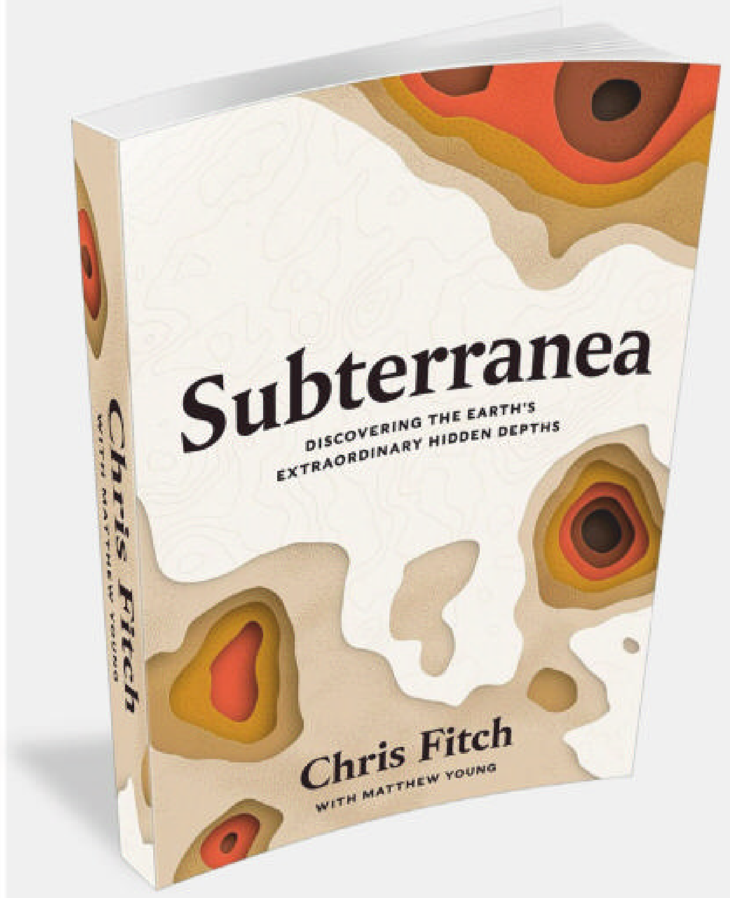

MICHAEL E. McCULLOUGH
The Kindness of Strangers
How a Selfish Ape Invented a New Moral Code
STEVEN PINKER
MICHAEL E. McCULLOUGH

Do you consider yourself to be kind? Whether it's the small act of holding a door open for somebody or the significant, life-saving act of donating an organ, there are so many ways that our species look out for others on a daily basis. Socially we are unique and complex beings, but when did we come to be kind?

Psychologist Michael McCullough has prepared an answer for you, taking you through the history and evolution from selfish ape to human. Backing up his reasoning with the work and findings of historians, psychologists and other scientists, McCullough explains how mass suffering, such as during the crises of wars, has created significant behavioural changes. Did our brains evolve to offer kindness for survival, or was it a more forced alteration?

Exploring the journey from our xenophobic ancestors to the science and technology aiding our psychology today, this book is an intriguing read for anyone interested in our social evolution and the paths that defined us.

★★★★☆



Subterranea

Discovering the Earth's extraordinary hidden depths

- Author: **Chris Fitch**
- Publisher: **Wildlife**
- Price: **£25 (approx. $31.60)**
- Release: **3 September**

From the luminous Waitomo Glowworm Caves to the futuristic Los Angeles tunnels, Chris Fitch takes readers on a journey beneath the surface to discover underground metropolises of natural wonder, unearthed archaeological sites and human-made masterpieces. With 40 different locations around the world to discover, you might wonder if this book could get repetitive. However, nothing could be further from the truth. As a collection of short stories, Fitch enthusiastically reveals the science and history of each location, making it clear there is much more to a cave than you might think. Accompanied by stunning photography and illustrative maps, this book is a great way to escape from the outside world by diving into the depths of another.

★★★★★

> A great way to escape from the outside world

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 How much gas is in an average human fart?

○ A thimble full
○ A fizzy drink can full
○ A wine bottle full
○ A kitchen sink full

Q2 How fast does sound travel in space?

○ 0 metres a second
○ 343 metres a second
○ 1,000 metres a second
○ 300,000km a second

Q3 Which was the first rocket to take a satellite into space?

○ Falcon 9
○ Saturn V
○ Long March 1
○ Sputnik

Q4 How many kilometres of nerves are in the human body?

○ 0.6
○ 6
○ 60
○ 600

Q5 Which living penguin species is biggest?

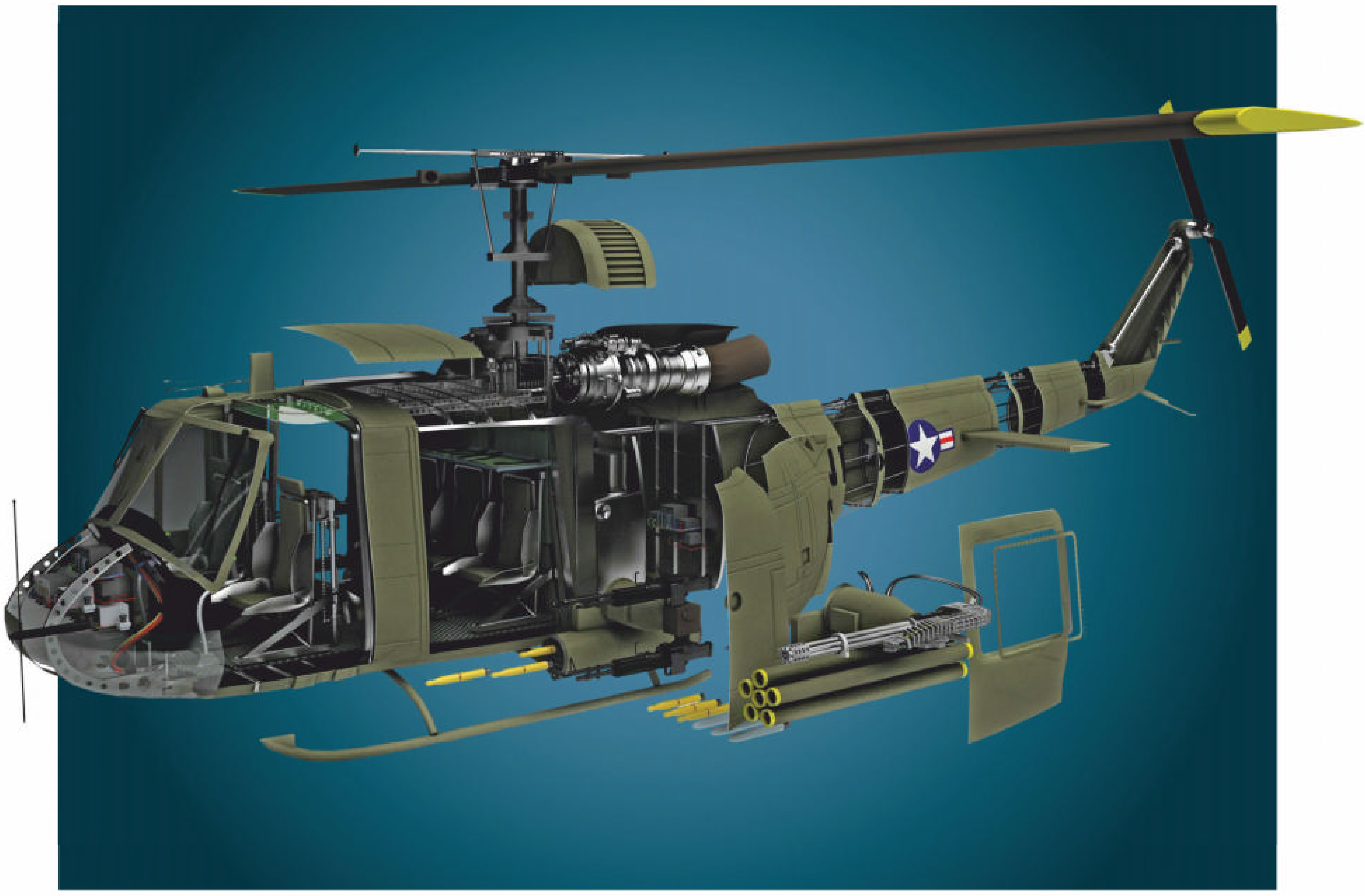
○ Emperor penguin
○ Little penguin
○ King penguin
○ Galápagos penguin

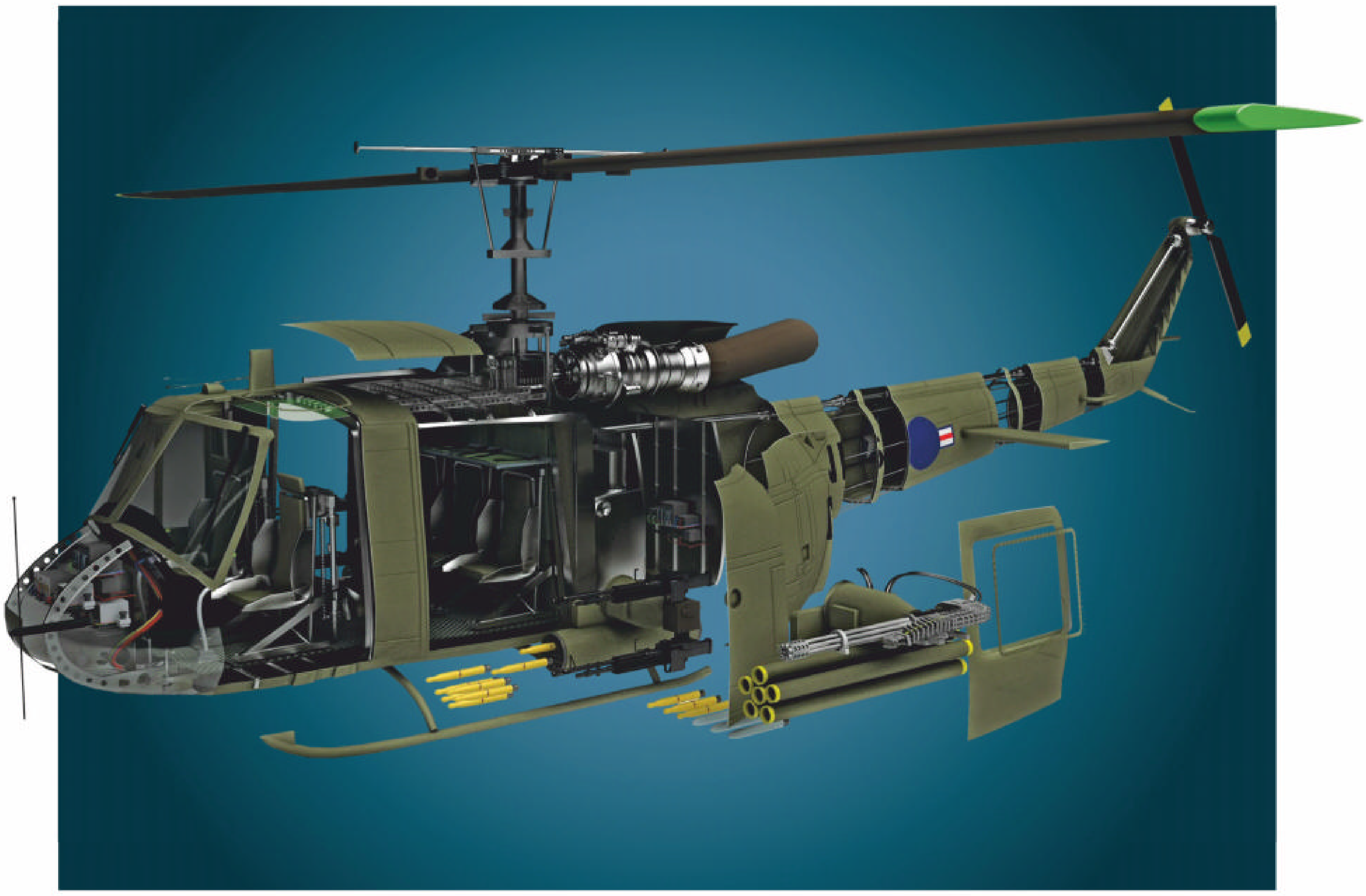
Q6 How heavy was the record-breaking crocodile Lolong?

○ 775 kg
○ 1,075 kg
○ 1,775 kg
○ 3,775 kg

Spot the difference

See if you can find all six changes between the images below





Sudoku

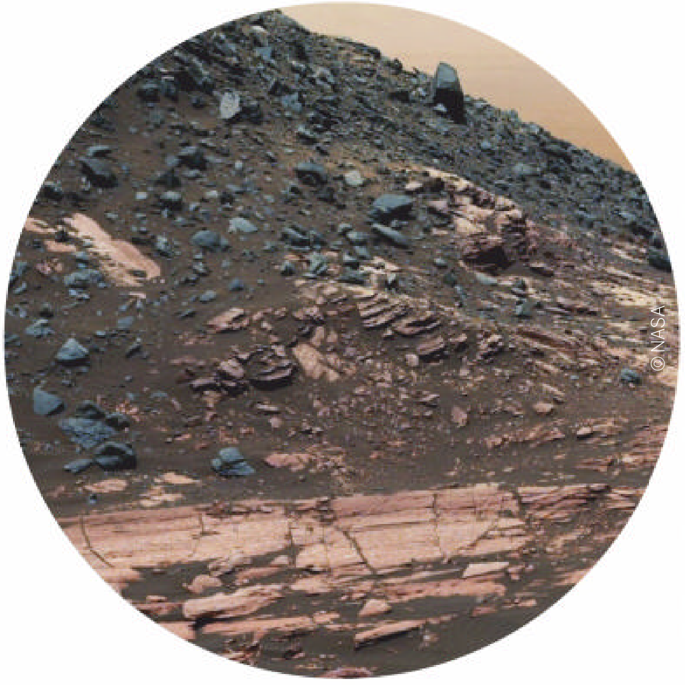
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

6	9	5	4	1	8			3
2	1	8		7	5			6
	7			9		1		
		1	5	6		9	3	4
	6				9			
	3	9	2	4		6		7
9						7		5
		6	7	5			2	
		3	9		6			

DIFFICULT

8		7			3			1
		1			2		4	
		5	1	8	7			
			5			7		
	6				9			4
	3					5		
			8	7	4			
		6						
				6		1	9	3


© NASA

What is it?

Hint: Can you guess which planet this photo was taken on?

A ....

A	L	P	O	X	I	K	S	C	I	A	L	T	S	Q
N	P	T	O	H	G	A	L	A	X	Y	J	N	C	U
R	I	E	M	F	O	R	D	E	N	L	O	R	I	M
Y	M	N	Z	A	L	I	X	Q	U	B	I	G	E	H
E	P	I	P	L	O	R	E	K	N	U	B	E	N	C
W	L	O	R	C	S	T	S	I	Y	N	M	E	T	X
T	E	B	J	O	I	B	A	G	A	C	F	P	I	Y
N	E	R	G	N	I	L	P	N	E	R	V	E	S	M
U	H	G	S	E	T	R	O	M	I	C	S	T	T	U
R	E	N	E	N	G	I	N	E	O	C	K	F	W	R
L	A	Y	A	T	S	O	P	I	Q	N	N	M	I	T
E	B	O	L	U	F	A	U	R	X	E	B	F	O	C
P	I	P	L	O	V	D	E	N	T	I	S	T	M	E
W	O	L	F	J	O	K	A	N	D	O	E	P	I	P
D	I	N	T	Z	X	F	V	O	T	E	I	A	V	S

Wordsearch

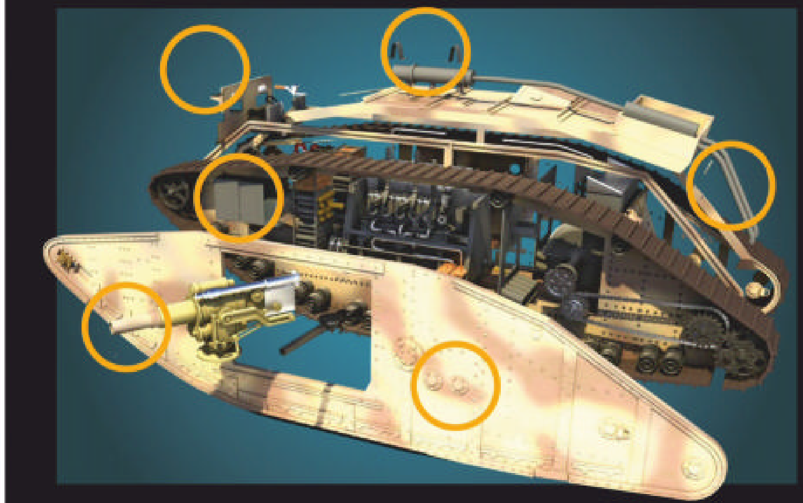
FIND THE FOLLOWING WORDS…

PIMPLE
ILLUSION
NERVE
SPECTRUM
GALAXY
FALCON
SCIENTIST
BUNKER
PIPE
VOTE
DENTIST
ENGINE

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 Strong wind damaged it
Q2 Broken arm
Q3 Beta-Carotene
Q4 Because it doesn't exist
Q5 On your skin
Q6 Mercury

WHAT IS IT? …SALMONELLA BACTERIA

© Getty

WIN! AN AIR COOLER

This month we are giving you the chance to win an evaSMART, the home-compatible app or voice-assist controlled evaporation air cooler, by evapolar.

For your chance to win, answer the following question:

Where in the human body would you find the uvula?

a) **Feet** b) **Stomach** c) **Throat**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 27 August 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **futuretcs.com**. Entries must be received by 00:00 BST on 27/08/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

HOW TO...

Practical projects to try at home

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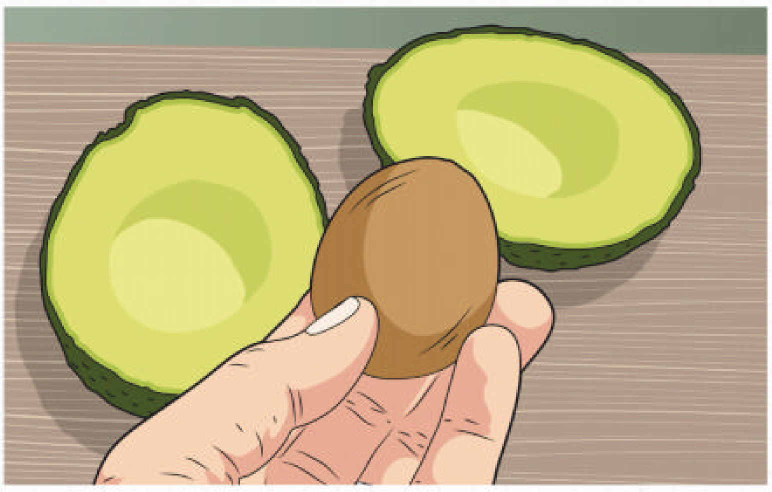
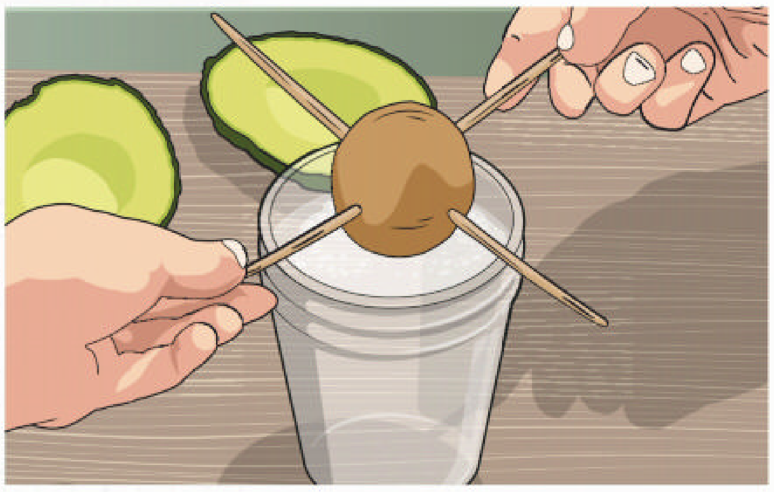
How to grow your own avocado tree

Watch your leftover seed grow from pit to plant



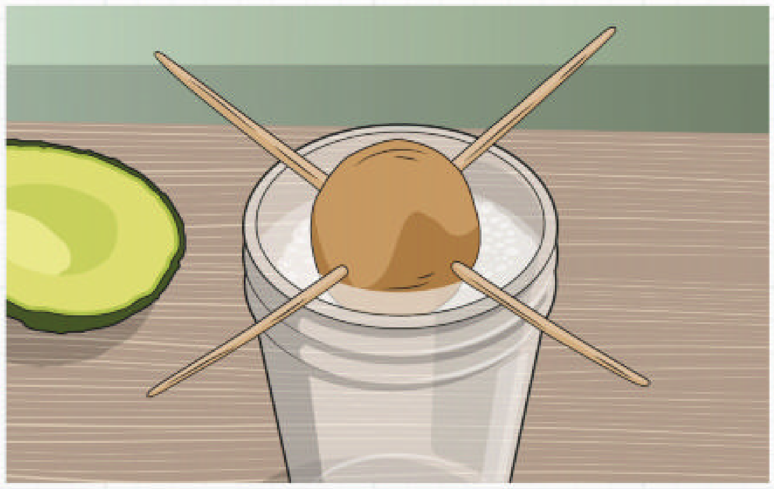
1 Gather your equipment

Extract the seed and clean it. Make sure the seed's brown skin remains intact. To begin the growing process you will also need four toothpicks, one drinking glass, a 25-centimetre pot and some potting soil.



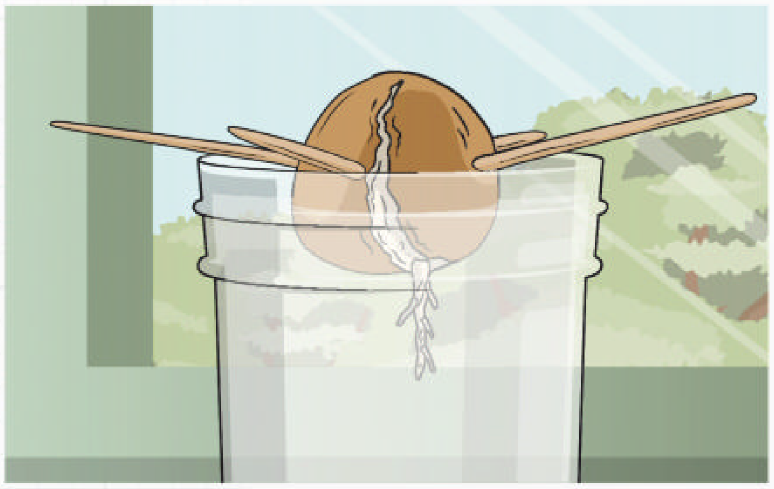
2 Pierce the seed

Hold the seed with the pointier end at the top. Making sure they are evenly spaced, insert your toothpicks firmly halfway up the side of the avocado seed and pointing slightly downwards into it.



3 Add the water

Balance the seed on the glass, using your toothpicks to suspend it. Fill the glass with water until only the bottom third of the seed is submerged. This water will need to be changed regularly and checked to keep the surface level constant.



4 Watch it sprout

The best place to leave the seed to sprout is somewhere warm. The time it will take to root and sprout can vary, but is usually between two and eight weeks. You will notice the seed beginning to crack at the bottom before this occurs.

5 Monitor growth

Measure the height of the avocado sprout as it grows. When it reaches 15 centimetres, cut it back down to half the size. Doing this will encourage root growth. It will soon return to the same height again, so don't worry about this impacting growth. Once it's taller again, it's ready to be moved.

6 New home

Plant the growing sprout into your pot, filled with potting soil. It will now have more space and nutrients to grow into a larger tree and needs access to sunlight. Remember to water your tree frequently to keep the soil moist, but not soaked. Occasional pruning will help produce a full and healthy tree.

© Illustrations by Ed Crooks

SUMMARY

Avocado trees make great houseplants, with the added bonus of them potentially producing new fruit. Some trees will bear fruit within three years, while others can take up to ten. Avocado trees thrive in warm weather, so the warmer the climate is, the more likely this will be. If you notice yellowing leaves, this is a sign you have overwatered the tree and should leave it to dry for a few days.

NEXT ISSUE

Make a tea light candle turbine

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind…

Get in touch

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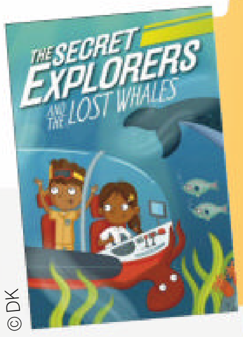


© DK

WIN!

THE SECRET EXPLORERS AND THE LOST WHALES

Dive into the world of The Secret Explorers and learn about ocean life in this action-packed first instalment in a brand-new fiction series.

© Mrs Monahan

This bread experiment can be found on issue 139's 'How to' page

Germ test

Hello **HIW,**

Toby carried out an experiment to find out how much bacteria was on his hands and his mum's mobile phone! Look at the results on the slices of bread. A timely reminder to keep washing our hands. Toby subscribes to the magazine, and by bringing it into school and showing others he has built you a wider customer base!

Mrs Monahan and Year 4

Thank you for showing us how Toby's experiment went. We are regularly told about the importance of washing our hands, especially in recent times, but this experiment is great for showing the presence of these invisible germs and how easily they can spread. We hope that the rest of your class found the results as interesting as we did.

Letter of the month

Lightning in the clouds

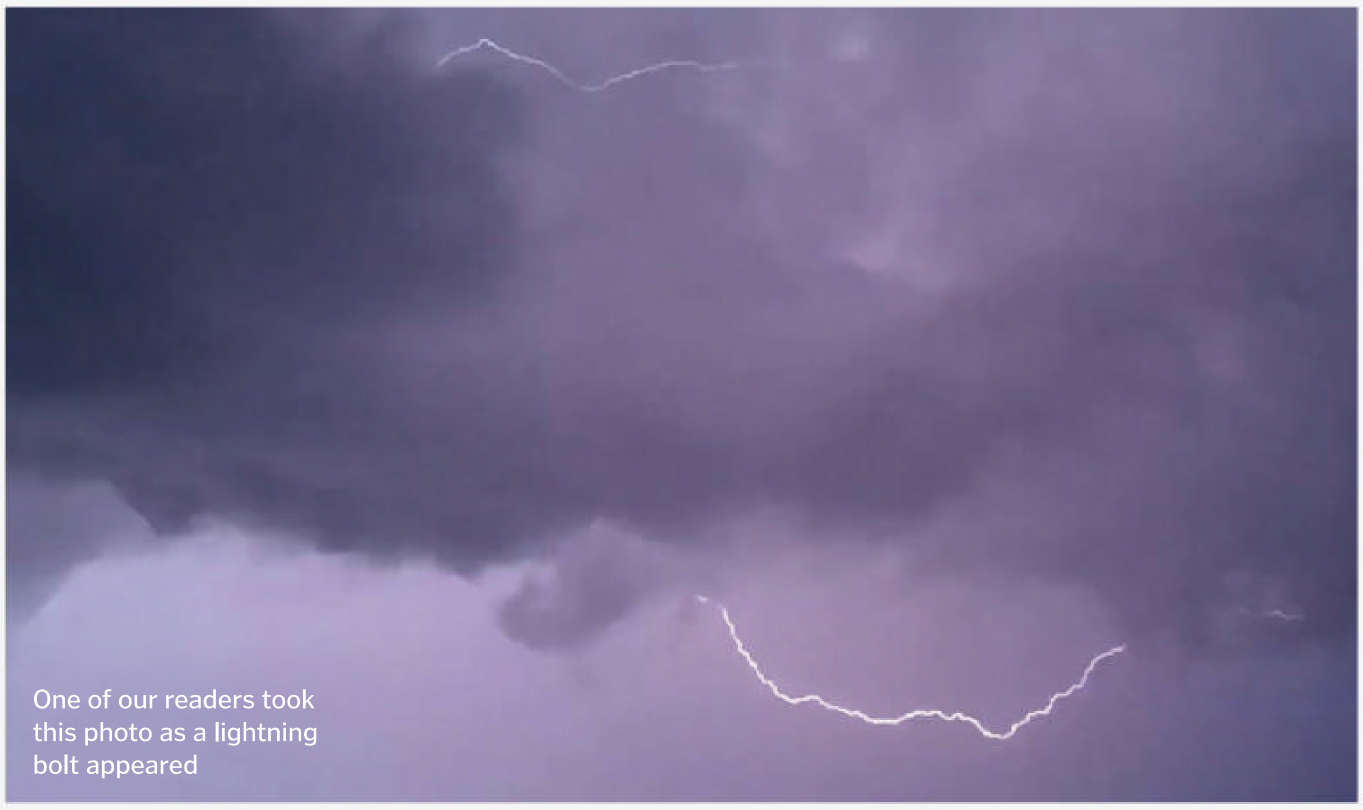
Hi **HIW,**

We have had a lot of thunder and lightning recently and I have managed to get some photos. I was wondering about what sort of lightning this was, as it seemed to go from cloud to cloud, not like forked or sheet lightning. Could you please explain what type of lightning this is and why it goes between two clouds?

Tessa

What a spectacular shot. This type of lightning is relatively rare, and you have captured a clear strike. When observing a thunderstorm, more often than not the lightning will travel from a cloud to the ground. But sometimes intercloud lightning takes place, with bolts travelling sideways. This is often called spider lightning, as it creeps horizontally underneath the clouds.

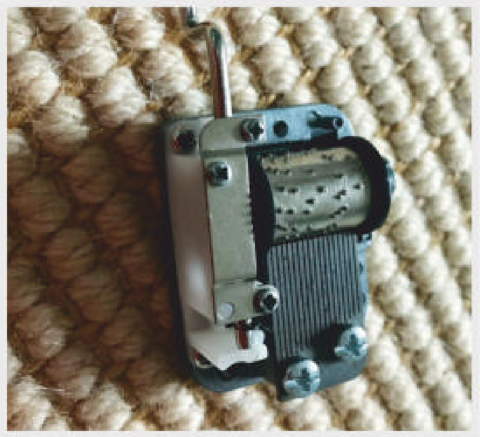
While sheet lightning never leaves a cloud, intercloud lightning can be seen leaving one and travelling to another. The area travelled to by the lightning depends on the surrounding electrical charges. Ice crystals and water droplets in the clouds create electrical charges, which then separate, with positive charges usually found at the top of a cloud and the negative sinking to the bottom. When the negative charges gain strength, lightning is drawn towards the nearest positive charge. If this is found in the surrounding clouds, this is where it will track to across the sky. Next time the sky lights up, keep a look out for the different paths and variations.



One of our readers took this photo as a lightning bolt appeared

© Tessa

Sound surfaces



The pins on the metal cylinder pluck the prongs below

© Edward Brocklehurst

Hi **HIW,**

I love your magazine and have been subscribed for many years. I bought a music box a few years ago that plays Für Elise. I noticed when I play it on top of wood it sounds very different to when it is played on my carpet. Why is this?

Edward Brocklehurst, age 16

This has fascinated many people since the music box was invented in the late 1700s. When placed on a hard, flat surface such as the wood you mentioned, the sound produced is much louder and clearer, while on the carpet you have pictured it playing on, some of the sound is lost.

The reason behind this is down to how sound travels. Sound waves are vibrations, and once produced in the music box they will bounce off the surface it is placed on. While flat surfaces project the sound more evenly back towards you, softer surfaces will absorb more of these vibrations, creating muffled music.

NEXT ISSUE…

Issue 142 on sale **3 SEP 2020**

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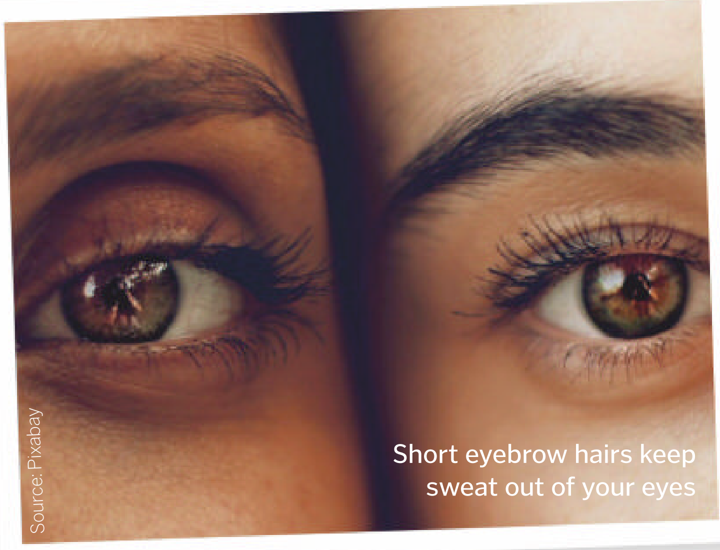
Let it grow

■ Dear **HIW**,

I am an avid **HIW** reader. I love the variety of topics you cover! I have a question that has been bugging me for a while. Some hairs on the human body can grow infinitely, like those on the head, while others don't grow beyond a certain length, like eyebrows. How does the body distinguish between those? Where does this 'hair-intelligence' reside in our body?

Prachi Mlittal


Short eyebrow hairs keep sweat out of your eyes

Source: Pixabay

Thank you for your letter, Prachi. Hair is a pretty impressive addition to the body of modern humans. While our ancestors would have had thicker coverings of it, we have selective patches with an incredible range of lengths. Each hair follicle has its own cycle, depending on where it is on the body. They produce new cells for a period of time – causing hair to grow – before resting, shedding and restarting. It is the duration of this growth phase which determines each hair's length. The length of your hair in different areas is determined by your genetics, and we as a species have evolved to sustain hair properties suitable for their purposes. Scientists believe chemical signals from stem cells provide follicles with area-specific instructions.

Frozen facts

■ Hi **HIW**,

I absolutely love your magazine. I find it so fascinating and it has a really engaging layout. I love brain dump. I am always asking random questions, so it's nice to know that I'm not the only one! I do have a question that's been bugging me for a while. If the polar regions are so cold that there are icebergs and everything is frozen, then why is there still water? Why hasn't all the water frozen over?

Jazz

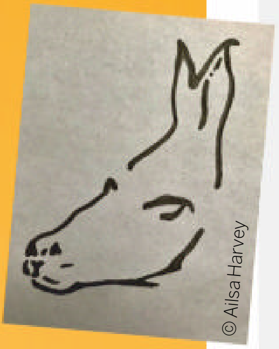
We love to hear your feedback and explore the questions our readers have. While it is possible for the ocean to freeze – the North Pole's polar ice cap is a layer of frozen seawater – the ocean needs much lower temperatures than freshwater to freeze. The snow, glaciers and icebergs that you mention are actually thick masses of frozen freshwater, not salty seawater. The high volume of water in the sea, currents distributing warmth and the salt preventing freezing are all factors in this case.

Icebergs are made of freshwater, not seawater

Source: Pixabay

What's happening on...
social media?

This month we asked you what animal you see when you look at this optical illusion


© Ailsa Harvey

Kathy O
Donkey, seal

@zidaneyvt4
Kangaroo's head

@ftmsnn_
Horse and dolphin

@scimaxfacts
I see a donkey as well as a seal! Keep up the great work

Paige A
Kangaroo, then seal

Evan H
Horse with its ears up, oddly enough!

HIW:
This is an example of an optical illusion that can be perceived in more than one way. Your brain will either interpret the image as the head of an animal, with its ears at the top, or the body of a seal, with the ear shapes taking on the role of the seal's flippers. This is based on the familiar shapes your eyes see first. On social media the majority of all responses included either 'kangaroo' or 'seal', and most saw the head of an animal before then seeing the seal.

HOW IT WORKS

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RED HAS THE LONGEST WAVELENGTH IN THE VISIBLE SPECTRUM

SEVEN KILOGRAMS

DWARF CROCODILES ARE TINY – ABOUT AS BIG AS A BABY SALTWATER CROCODILE

126 MILLION

EACH OF YOUR EYES CONTAINS MILLIONS OF LIGHT RECEPTORS CALLED RODS AND CONES

0.000000000230 METRES

THE SMALLEST MANUFACTURED ENGINE IN THE WORLD IS THE SIZE OF A SINGLE ATOM

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HISTORY OF THE BRITISH FIGHTER SPITFIRE MK VB

A single-seat, single-engine all-metal monoplane fighter. After the Mk II and two more experimental variants of the Spitfire, the next major variant to see mass production was the Spitfire Mk V. Central to this new Spitfire was its engine – the 1470 HP Rolls Royce Merlin 45. This was equipped with a single stage supercharger and, coupled with a new carburettor design, allowed the Mk V to perform zero G manoeuvres without starving the fuel flow to the engine; a problem which had plagued earlier models of the Spitfire.

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